VOLUME 51 NUMBER 11 . . . ONE YEAR THREE FIFTY

GENERAL ELECTRIC REVIEW

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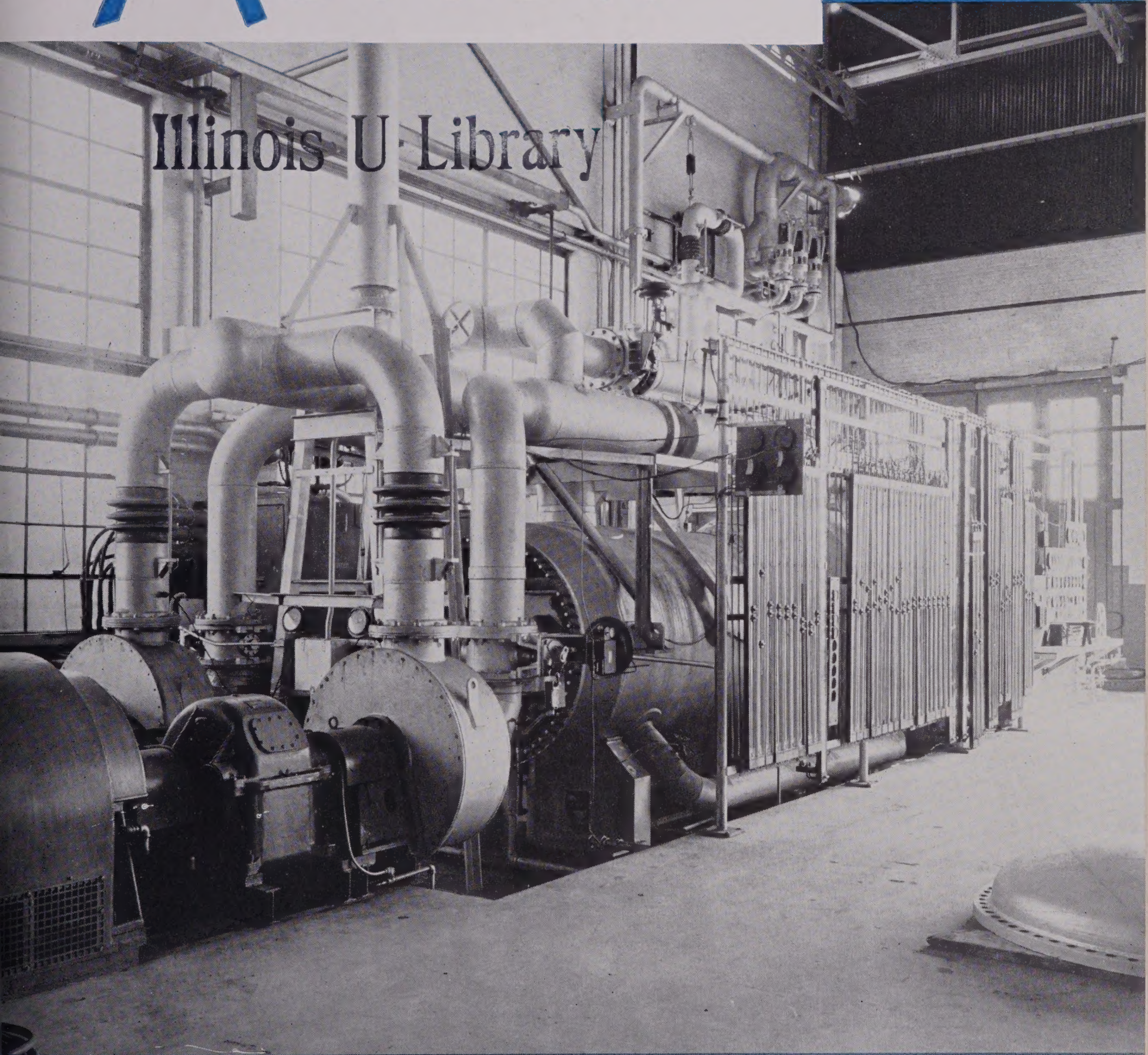

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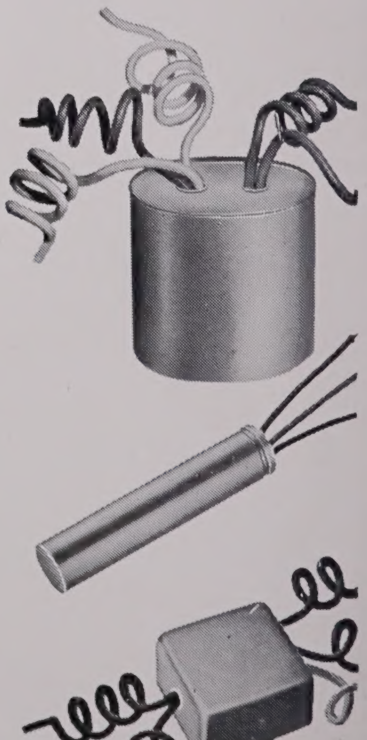

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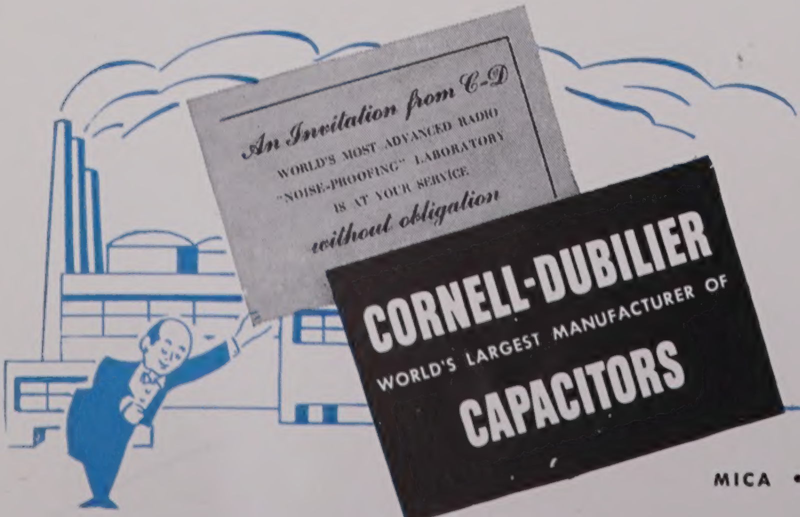

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GENERAL ELECTRIC Review

NOVEMBER, 1948
Vol. 51, No. 11

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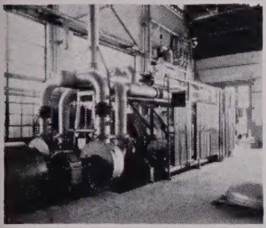

THE COVER

A test stand in General Electric's new aircraft gas-turbine research laboratory at Lynn (Mass). One of four specially designed pieces of apparatus for obtaining basic data on jet-engine compressors, combustion systems, and turbines, this equipment tests 15-in. scale-model compressors in an atmosphere simulating extreme flight conditions. Another of these specially designed testing equipments, the one for testing full-scale compressors, is pictured on page 42. Altogether, these new laboratory facilities provide means for meeting the research challenge described in the article by Mr. Stoeckly in this issue.

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CIRCULATION DEPARTMENT: General Electric Review, Schenectady 5, New York.

SUBSCRIPTION RATES: *Payable in advance.* United States and Possessions and countries in Pan-American Union, one year $3.50, two years $5.50. Canada, one year $3.75, two years $5.75. Other foreign countries, $4.00 a year, $6.00 two years. Public and college libraries, professors, and enrolled students deduct $1.00 from annual rates. SINGLE COPY 35¢

CHANGE OF ADDRESS: Give old and new addresses. Notices received before the fifteenth of the month will be effective with the next issue.

ADVERTISING DEPARTMENT: General Electric Review, Schenectady 5, New York.

Entered as second-class matter, March 26, 1912, at the post office at Schenectady, N. Y., under Act of March 3, 1879. Published monthly by General Electric Company, 1 River Road. Schenectady 5, N. Y. Printed in U. S. A. *Copyright 1948 by General Electric Company.*

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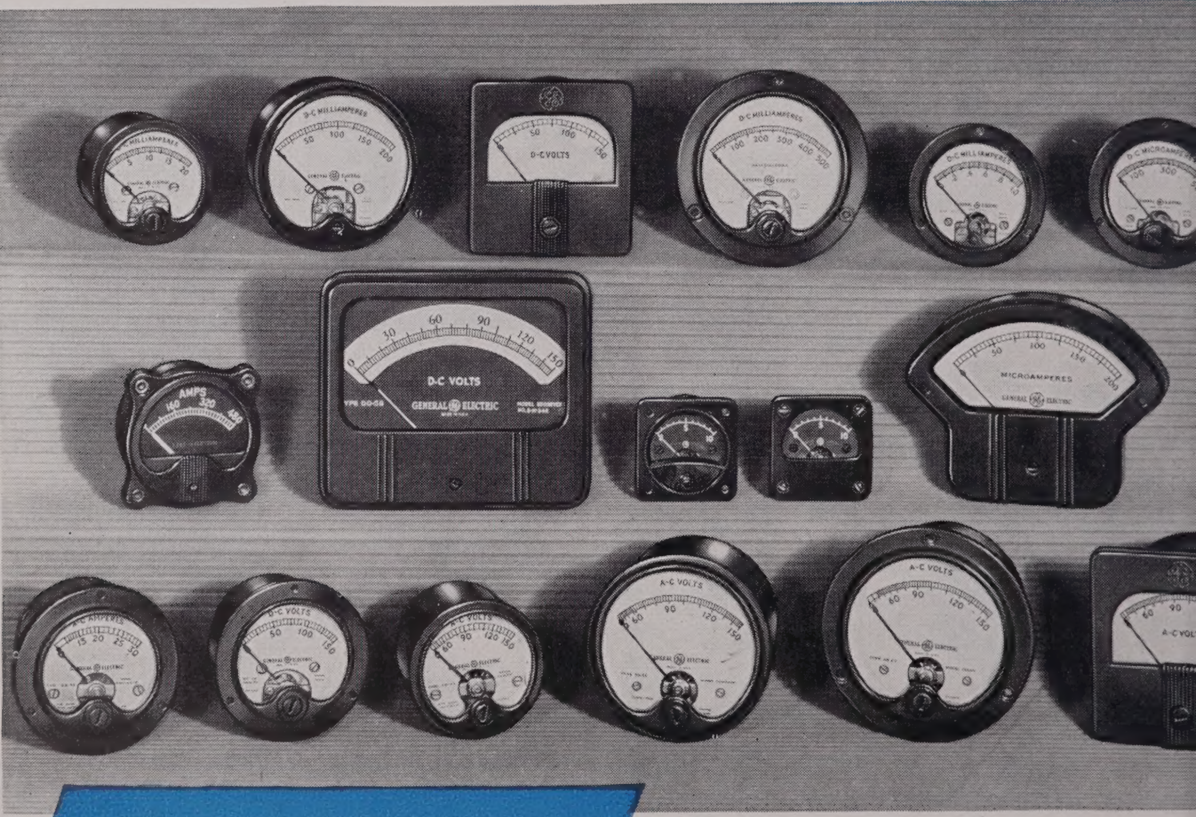

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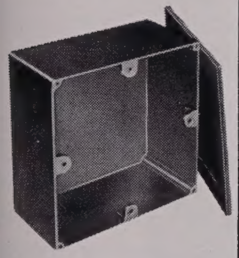

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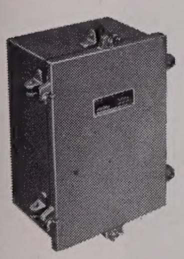

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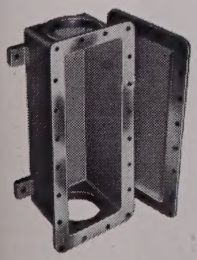

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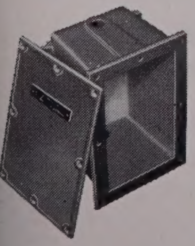

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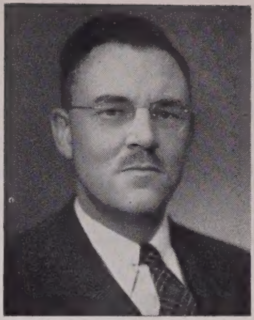
THE HOUSE THE RESEARCH LABORATORY BUILT
(See page 11)

HE RESEARCH LABORATORY BUILDS A HOUSE

The latest architectural achievement in providing means for facilitating scientific research. The laboratory's philosophy of operation, the supply of services, and the structural features of the buildings—all of which combine to accelerate the already rapid pace with which General Electric is exploring various fields of science

By DR. H. H. RACE
Research Laboratory, General Electric Company



Hubert H Race

THE project of co-ordinating the planning for new buildings and facilities to house the many activities the Research Laboratory of the General Electric ompany began in January 1945. The job was first to certain the requirements in terms of types and antities of services and structures needed, and then help convert plans and new ideas into the buildings hich we began to occupy this autumn.

The execution of the necessary design and construc- on work was assigned to the General Electric Realty orporation, which is responsible for the acquisition new properties and for the design of the General lectric Company's new plant facilities. The Realty orporation selected the firm of Voorhees, Walker, oley & Smith, Architects; and the George A. Fuller ompany as General Contractors.

HILOSOPHY OF OPERATION

Early in our considerations it became apparent that e physical arrangement of buildings and services ould be dictated in large measure by the philosophy operation of the laboratory. A few of the more nportant factors will be mentioned.

lexibility

Our experience has been that problems and methods experimentation are always changing so that flexi- ility of partition, furniture, and service arrangements ould be as great as possible. If there is one thing we now, it is that we do not know now what we will be oing ten years from now.

niversality

As investigational projects change, space require- ents and experimental equipment to be housed in the ace may change also. Furthermore, the lifetime of a ilding should be fifty years or more and one cannot w guess the nature of the work that will be in progress far in the future. Therefore, it seemed desirable to sign a building in which much of the space should be niversal space" in which any available research cilities could be installed in any room as desired.

Interrelation of Sections

It has been a practice in our laboratory to encourage free interchange of ideas among all scientists in all sections. As the laboratory has grown this has been less automatic, nevertheless the policy of the laboratory is definitely opposed to separation into distinct, self-sufficient, autonomous groups in the belief that in modern complex scientific research the sum of the efforts of many persons working together is greater than the sum of their individual contributions working separately.

Furthermore, the project method of attacking research problems requires the efforts of individuals having many kinds of specialized training. Flexibility in personnel assignments is necessary in order to focus on a particular job at a particular time the required physical, chemical, metallurgical, or other specialized knowledge. For this reason, insofar as practicable, it was decided to house the scientists in one large building rather than in a group of separated smaller buildings.

High Level of Service to Research Spaces

The largest item in a research laboratory budget is pay for researchers' time. Consequently a large capital investment in specialized buildings is justified if it provides convenient services to make experimentation easier and faster. Therefore the main building is so designed that in any room (FIG. 1) there is available any or all of the following pipe services: hot water, cold water, distilled water, laboratory drain, hydrogen, nitrogen, oxygen, city gas, compressed air, rough vacuum, and 125-lb steam. Furthermore, experience teaches that the level of demand for electric service for experimental work is continually increasing so that the following electric services are available in any room if desired: 120/208-volt 3-phase 4-wire 60-cycle power; 265/440-volt 3-phase 4-wire 60-cycle power; and ±125/250-volt direct current.

Central Shops

It seems impossible to completely satisfy the demands of experimental researchers for shop facilities. It is known that items of equipment which can be purchased as stock items cost less than when made one

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This article is so paged that without mutilating other articles, it can be dily removed for filing as a group of full-size consecutive pages.—EDITOR at a time in our own shops. Therefore, whenever possible, standard items of equipment are purchased. On the other hand, special experimental tools and apparatus are more easily made in our own shops where the scientist can have the invaluable aid of good craftsmen either in "haywiring" together a "quick and dirty" gadget if that is all that is required or in designing and constructing apparatus of considerable complexity and closest possible dimensional tolerances where such is required. Many an experimental setup is improved by the practical experience of the craftsmen who build it.

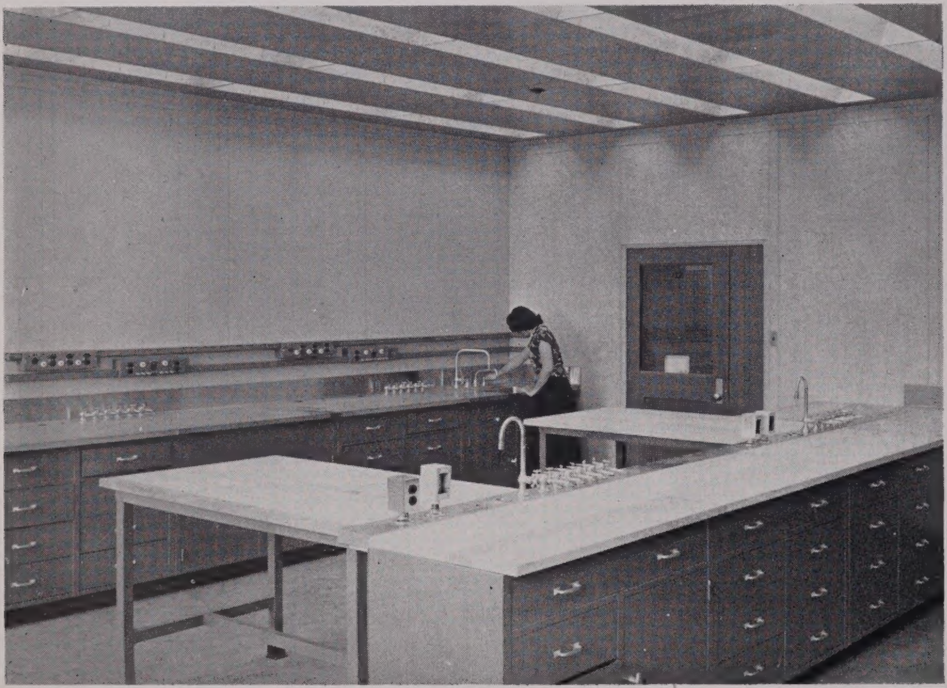


Fig. 1. Convenient availability of ele and pipe services in the laboratory ro is a contributing factor to effective ex mentation

For these reasons the shops should be as nearly as possible in the physical center of the research space. Also, within the limits of good management, all the scientists should have as easy, as friendly, and as informal access to the craftsmen who work with and for them as is possible.

Specialized Buildings

There is a repeating chronological pattern followed by many research developments, namely:

(1). Small-scale or "test-tube" experiments to seek new scientific knowledge or to try out theoretical hypotheses.

(2). Larger-scale or "batch-size" experiments to prove or improve results obtained in the small-scale tests.

(3). Semiproduction or "pilot-plant" operations with products or processes which show promise of being useful as the result of the smaller-scale trials.

The general research building should be designed to house adequately the first two of those classes of work. In many cases, however, the general research building is not suited for pilot-plant-scale operations which c be more effectively and more efficiently conducted buildings designed for this specific purpose.

The specialized research space is dictated not only the chronology of research projects—for example, pilot-plant stage—but also by special requireme which may not be available in universal laborat space. Typical specialized requirements are: high he room, explosion-venting walls, radiation shielding, a the like. Therefore, adjacent to the general laborat building there may be need for a number of separ specialized buildings each designed for a particular ty of work. Examples in the new project are: a Radiat Laboratory, a Low Temperature Laboratory, a Che ical Pilot Plant, and a Fluid Flow Laboratory, th of which are now under construction.

Safety

While many features of construction are dictated considerations of flexibility, serviceability, and l useful life, the designer must be mindful of the need building safety into all features of laboratory operati A number of factors that contribute to safety are:

(1). Laboratory room doors open outward fr the rooms into the corridor (FIG. 2) for ease of egr Each 4-ft-wide doorway has a 1-ft-wide hinged pa which is normally bolted closed and a 3-ft-w active leaf opening into a vestibule between serv shafts. This door has a clear-glass panel to prov visibility for guarding against collision with some approaching the other side. Also, the door wh open does not protrude into the corridor, thus avo ing collisions with passers-by.

In general, two means of egress have been p vided from each laboratory room in which hazard work may be done. If the room is so small that it is not convenient to have two doors, escape hatches into an adjoining room have been provided at the end of the room far from the door.

(2). For fire fighting, portable 3-, 5-, or 10-lb CO$_2$ hand extinguishers are provided, at least one per room and in some areas one per worker. In addition, at each stairwell on each floor 50-lb CO$_2$ carts are located in cabinets off the corridor. Our experience is that all but extremely unusual fires can be put out quickly with hand CO$_2$ extinguishers. As far as possible all laboratory furnishings are nonflammable; partitions and furniture are steel, bench tops may be wood, the floor covering is asphalt tile, but otherwise the only combustible materials are those with which the occupant is working.

In standard research space thermostatic-type fire detectors have been installed on the ceilings with zoned drop-type indicators in the electrical control room where an operator will be stationed at all times. Basement and shop areas are protected with standard water sprinklers.

(3). All electrical and pipe services can be turned off in the shafts where they take off from the vertical feeders. Thus in the event of trouble in any room the services to the room can be turned off from the corridor without entering the room.

(4). For many years safety committees have been urging the use of solid protective grounds in addition to normal neutral wires on all electric systems. For example, single-phase lines would use three-prong plugs and sockets with the third or protective ground wire providing a means for connecting machine frames or equipment chassis solidly to ground independent of the electrical neutral or of the metal conduit whose continuity might be imperfect. Likewise, three-phase plugs without neutral would be four-prong so as to carry the protective ground wire. Furthermore, four-wire three-phase circuits in which the neutral is also carried through so that line-to-neutral voltage is available would require a fifth wire for the independent protective ground.

This system has been followed throughout the new laboratory so as to guarantee the greatest possible safety protection against accidental electric shocks. The protective ground network is also solidly connected to the steelwork of the building frame, all metal pipes, and the steel partitions at many locations throughout the building. Furthermore, this network is connected to a grid of ground rods and cable in the earth outside of the building.

ELECTION OF SITE

The General Electric Research Laboratory has been notable pioneer in promoting fundamental research industry. The close association of fundamental rearch and the opportunity of applying it to the soluon of practical problems has in some cases created, and in other cases greatly expanded, important new segments of industry. The application of research to engineering practice requires a close contact with all engineering, designing, and manufacturing departments of the Company. This is a difficult problem because the General Electric Company has grown until it now has over one hundred manufacturing plants from Massachusetts to California. The engineering effort with which the closest contact is desired, however, is to a large extent in the east, with Schenectady near to the center of gravity of this work. This fact dictated the necessity of locating the new laboratory near Schenectady.

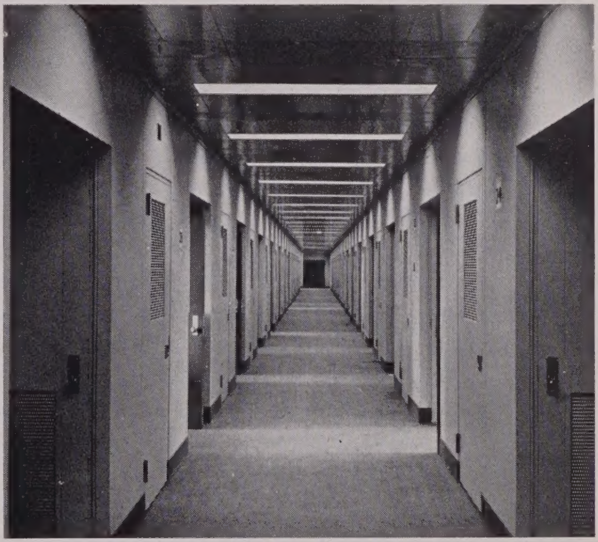


Fig. 2. A typical corridor that provides unobstructed passageway from end to end of the building and convenient access to research areas and the distribution of services

An area on the Mohawk River just outside of Schenectady was chosen as most nearly filling the foregoing and some additional important requirements. The area takes its name from one of the properties acquired, an estate called "The Knolls." The first reaction of a visitor to the site is the beauty of its natural setting on the highest part of the immediate surroundings on the south bank of the Mohawk River.

While we are not unmindful of natural beauty, our choice of the site for a Research Laboratory was based on many other desirable features which it also provides. For example:

(1). The Mohawk River could provide practically unlimited quantities of cooling and process water.

(2). The river furnishes means for disposing of liquid wastes after they have been properly neutralized and purified.

(3). The river can permit barge transportation for fuel oil or for specially bulky or heavy equipment if desired.

(4). Close to the river bank is a branch railroad line of the New York Central System running through the property and giving necessary shipping facilities for materials and equipments.

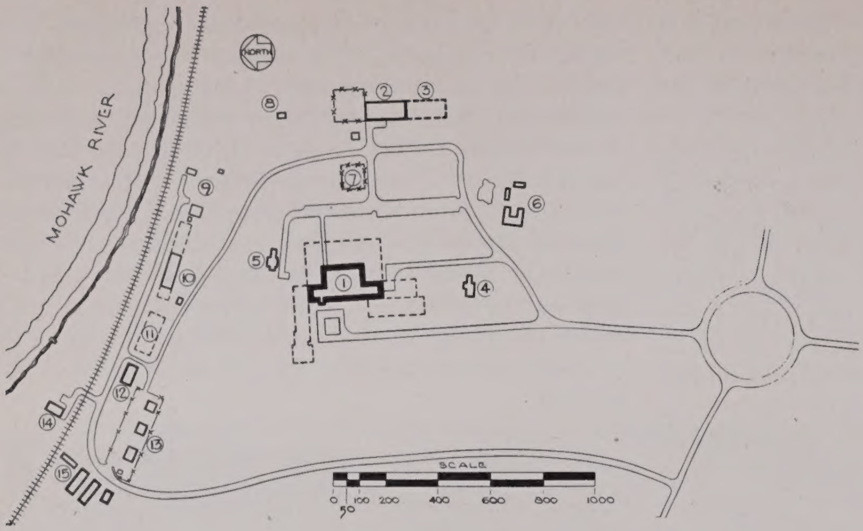


Fig. 3. General plot plan of the Research Laboratory area

1: Main Laboratory
2 and 3: Radiation
4: Cafeteria
5: Guest House
6: Storage Barns
7: Power Substation
8: Water Tower
9: Sewage Disposal Plant
10: Steam Plant
11: Mechanical Pilot Plant
12: Chemical Pilot Plant
13: Gas Storage
14: Low Temperature
15: Storage Area

(5). Near the site are good residential areas and it is surrounded by large zoned areas for future home developments.

(6). The Knolls is only five miles from the Schenectady Works of the General Electric Company which is not only the largest single manufacturing plant of the Company but also the home of the Apparatus Department's general offices, the Patent Department, and the General Engineering and Consulting Laboratory, the latter two of which serve the entire Company, and with all of which the Research Laboratory desires close contact.

SUPPLY OF SERVICES

Moving the Research Laboratory from the Schenectady Works to the Knolls is in many respects like a child taking leave of its parents to make his own way in the world. He finds very quickly that he has been taking for granted many important services for which he must now spend money and energy to supply for himself. Among the things which were formerly given little thought and paid for as rent, and which we now must provide for ourselves, are:

(1). A steam-generating plant for steam heat.

(2). A substation to receive electric energy purchased from the New York Power & Light Corporation.

(3). A gas-compressor house to receive city gas purchased from the same public utility.

(4). An automatic telephone exchange.

(5). A water tower and fire pumps to receive water purchased from the city of Schenectady through the town of Niskayuna.

(6). A sewage-disposal plant to purify and neutralize both sanitary and industrial wastes.

(7). A gas-receiving and purification plant to store and purify for laboratory use large quantities of hydrogen, nitrogen, and oxygen.

The cost of providing such services, with attendant underground pipes and ducts between buildings, represents 30 percent of the initial investment in t site. FIG. 3 shows a plot plan of the area with a list the various research and service buildings now be completed. Dotted lines show provisions for fut wings on the main building and future additions other buildings. All ground services have been installed as to avoid interference with such future c struction and yet at the same time to facilitate extension of the services at a later date to the fut buildings.

MAIN BUILDING DESIGN

Close Juxtaposition of Research Space and Shops

Full advantage has been taken of the contour of land and of the use of elevators to provide the desi easy access of research personnel to the shops attach to the main building. FIG. 4 shows a floor plan indic ing stairs and pairs of automatic push-button passen elevators at each end of the structure. At the south c is also a freight-handling area on each floor off main corridor, with an automatic push-button frei elevator and a larger hand-operated freight eleva which can carry equipment from the first floor the roof. All services are designed to accommod future wings as shown by dotted outlines in FIG. 3.

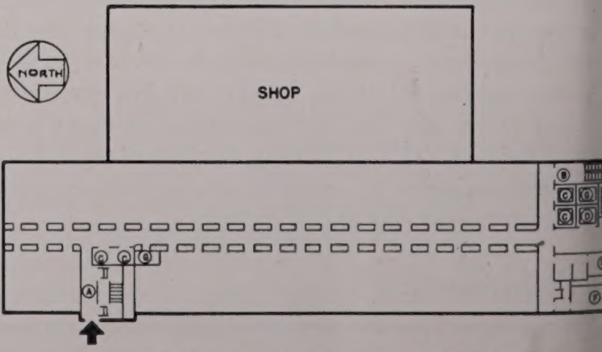


Fig. 4. Floor plan of the main building

A: Stair 1
B: Stair 2
C: Passenger Elevator
D: Freight Elevator
E: Women's Room
F: Men's Room
G: Vent Shaft

The knoll on which the main building is located is eally a long narrow ridge running approximately orth and south. The general research building's main ntrance on the west side of the third floor is level with he ground on the top of the ridge. The ground slopes ff to the east so that, as shown in Fig. 5, two stories of ull headroom shop space grow out of the first and econd floors of the building with consequent easy ccess by elevators and stairs.

Vindows and Window Module

One of the first decisions required was whether we vished a windowless building. The architects stated hat a building could be built cheaper without windows han with them. Lighting experts agreed that the rooms ould not be lighted adequately from windows alone so hat a satisfactory system of lighting must be installed vhether windows were or were not provided. Nevertheess, a representative canvass of our technical employees ndicated that many would prefer not to work coninuously in a windowless building.

Aluminum window frames and sash with built-in tainless-steel weather-stripping and double glazing vere selected because:

(1). We wished to minimize maintenance costs.

(2). Certain types of research require dust-free air and therefore tight windows.

(3). The building is in an exposed location where it will be subjected to strong cold winds in winter and we wished to avoid the necessity of putting up and taking down storm windows annually.

For best external appearance, a window module of 2 ft or more seemed desirable. On the other hand, ccupancy considerations indicate the necessity for ome narrower rooms and greater flexibility of internal artition arrangements than that given by a 12-ft or 8-ft internal module. A 12-ft external module was dopted with windows 5½ ft wide and pilasters 6½ ft ide.

artition Module

The exterior pilasters were made 6½ ft wide so as to llow three possible partition positions, the preferred one at the center of the pilaster or if desired 3 ft either side of that point. This makes possible rooms having widths which are multiples of 3 ft. Room widths which are multiples of 12 ft would be repetitive; the others could be arranged only in certain specific sequences. Illustrations of possible room widths are shown in Fig. 6. If one cross partition of a room is at the center line of a pilaster, the possible room widths are $12n \pm 3$ ft (where n is an integer). If one partition is at the edge of a pilaster (3 ft from the center line), then the possible room widths are $12n \pm 6$ ft.

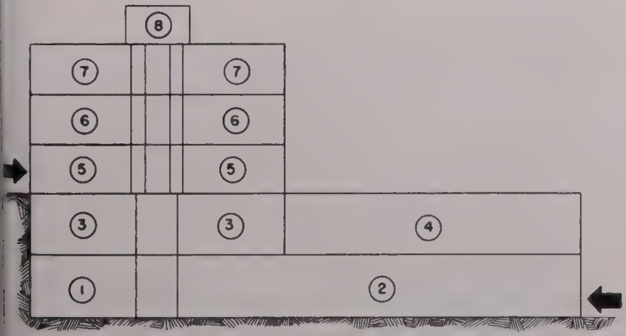


Fig. 5. Section through the main building

1: Research Space
2: Machine Shops
3: Service Floor
4: Glass Shops
5: 3rd Floor
6: 4th Floor
7: 5th Floor
8: Service Monitor

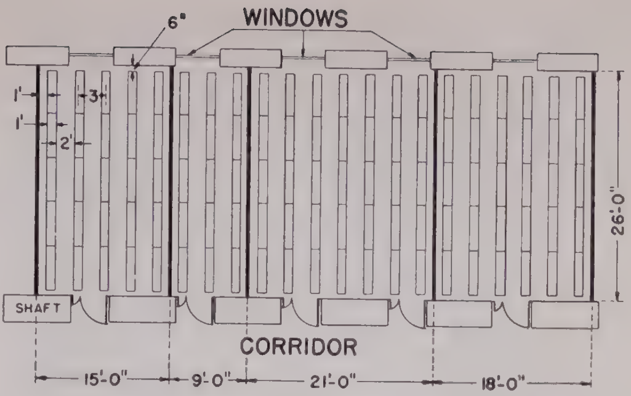


Fig. 6. Possible arrangement of room partitions with respect to windows, doors, and lighting fixtures

Room Door Module

It is necessary that the possible door openings into the rooms and the arrangement of lighting fixtures be consistent with the partition module. In our design the pipe, electric, and air services to the research rooms are provided in shafts 12 ft apart and on each side of a central corridor as will be explained later. A doorway is provided between shafts opposite each window, giving a door module also of 12 ft.

Experimentalists are finding use for many kinds of portable equipment that is mounted on wheels and that can be assembled and stocked in one place and transported easily to research rooms when needed. For this reason the doors from the corridors are made with two leaves as shown in Fig. 6. The small leaf is a hinged steel panel which is normally closed and bolted top and bottom but which can be opened to provide access for large equipment. The other leaf is a standard 3-ft glazed door.

RESEARCH ROOM LIGHTING

Discussions with our own personnel and with lighting experts resulted in the following conclusions:

(1). Lighting at the work benches should be about 50 foot-candles.

(2). Diffused light giving a good intensity of illumination on vertical surfaces so as to make it easy to read instruments such as meters, manometers, pipettes, and the like.

(3). Fluorescent lamps are preferable to incandescent lamps because they provide distributed light

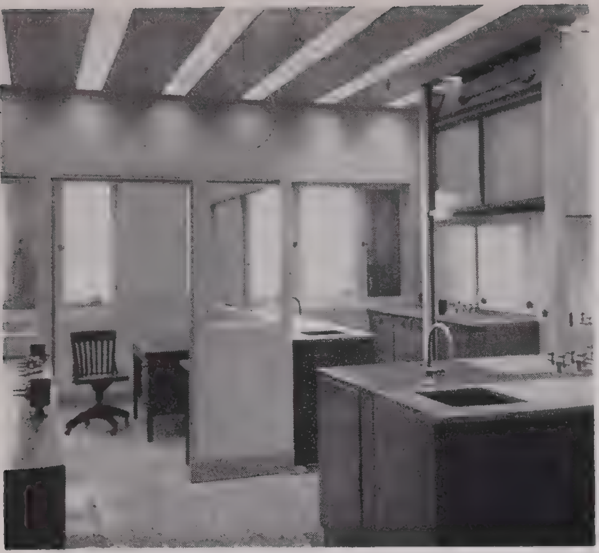


Fig. 7. Trial installation research room, including low-intensity fluorescent lighting

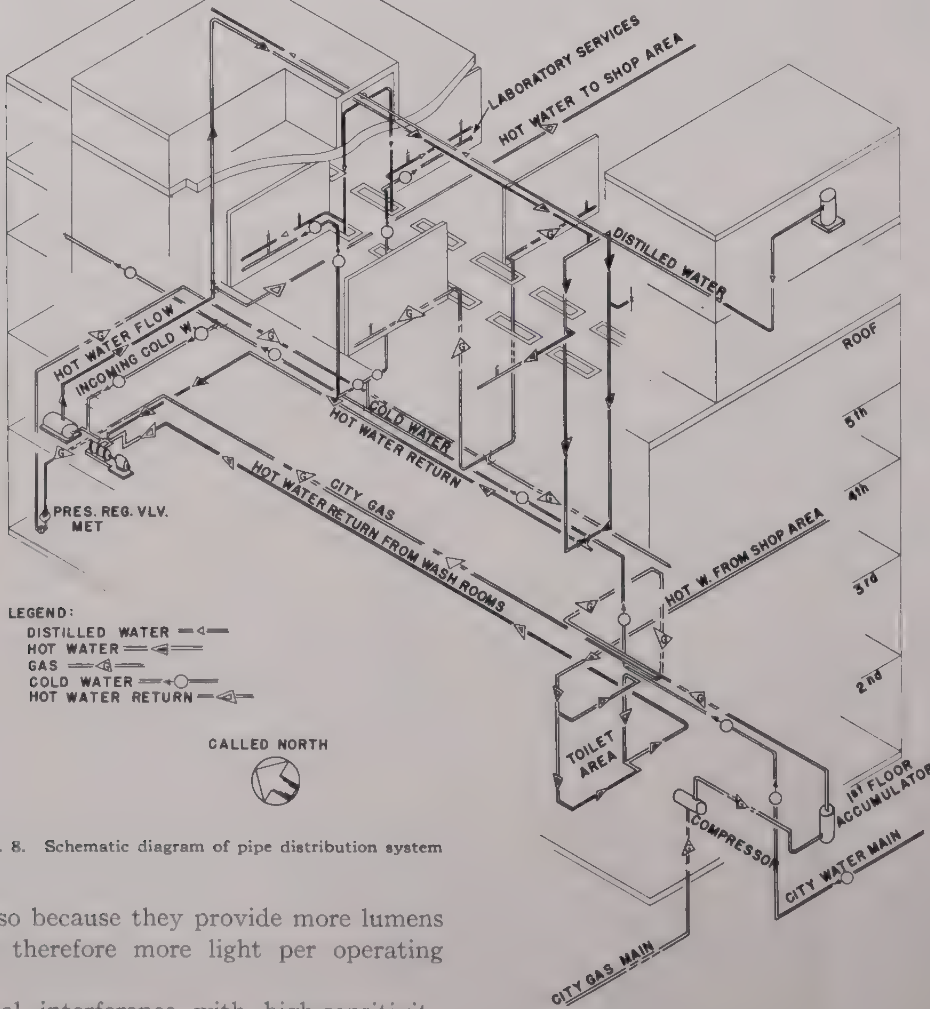


Fig. 8. Schematic diagram of pipe distribution system

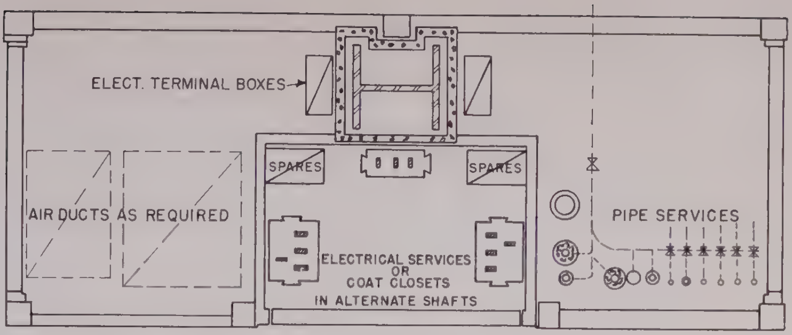
sources and also because they provide more lumens per watt and therefore more light per operating dollar.

(4). Electrical interference with high-sensitivity electronic equipment does not prohibit the use of fluorescent lamps because the operation of oscillators of various frequencies throughout the laboratory forces the general use of shielded cages for high-sensitivity apparatus.

The layout of the system of lighting finally chosen for the research rooms is shown in Fig. 6. The most important new feature of this installation is that 5-ft *low-intensity* lamps are used throughout. Each lamp is of the same size as the standard 100-watt (T-17) lamp, but has been modified for operation at 40 watts. This means that the intrinsic brilliance at the surface of the glass is only about 50 percent of that of the 100-watt unit, thus minimizing the sensation of glare in the room.

A trial installation (shown in Fig. 7) has been in operation for about two years. The recessed single-lamp troffers are made of aluminum with an "Alzak" finish which has a semimatt surface to avoid producing specular reflection and to provide considerable light diffusion. The troffers are 12 in. wide, and five units end to end occupy 25 ft out of the 26 ft clear distance from the inside surface of the outside wall to the room side of the shaft covering. Also as shown in Fig. 6, the center lines of these lines of lights are placed 3 ft apart and midway between possible partition positions.

Thus it is seen that the 3-ft lamp module is con-sistent with the partition, window, and door modules. The lines of lamps will be in the same relative position



g. 9. Plan of service shaft for vertical distribution of air, ectric, and pipe services

ith respect to cross partitions regardless of which artition position is chosen. Also, there will always e a line of lamps over benches or work tables along ne partitions so that persons conducting experiments n these benches will not be working in their own nadows.

In the trial installation, the lighting at bench height ter two years of lamp operation is 50 foot-candles. he lighting as measured on vertical surfaces 5 ft ove the floor is about 10 foot-candles. The energy quired to produce this illumination is less than 3 atts per sq ft of floor space. Furthermore, the illunation is so diffused and free from glare that it has en found unnecessary to use baffles in the light offers; and the general level of illumination has been adequate as to make unnecessary the installation of sk lamps in this office. The occupants of the room e very pleased with the lighting installation.

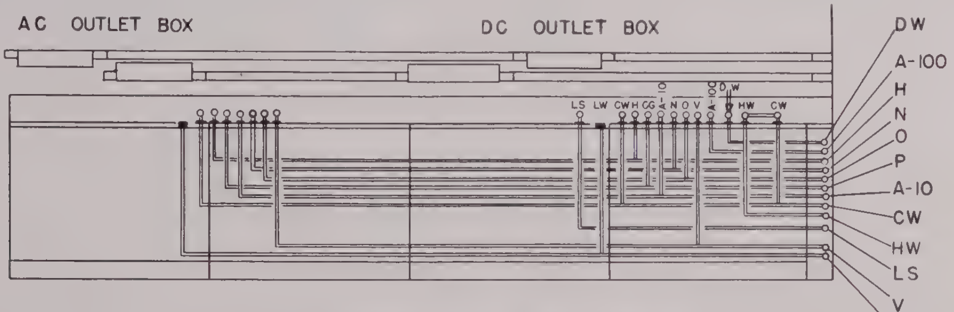
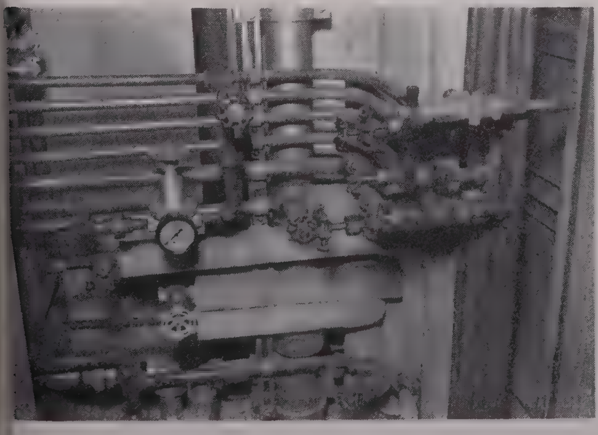


Fig. 11. Standardized service outlet arrangement

LS: Live Steam
LW: Laboratory Waste
CW: Cold Water
H: Hydrogen
CG: City Gas
A-10: Air at 10 lb
N: Nitrogen
O: Oyxgen
V: Vacuum
A-100: Air at 100 lb
DW: Distilled Water
HW: Hot Water



g. 10. Arrangement of pipes in a service shaft, viewed from access door

PIPE DISTRIBUTION SYSTEM

The backbone of the pipe distribution system in the main building is a set of horizontal mains along the ceiling of the second-floor corridor. Every 12 ft along the building, branch lines or risers extend up through the occupied floors in shafts on each side of the corridor. Each shaft carries all pipe services. Each service is valved at the lower end of each vertical riser. A take-off tee and valve are provided on each service in each shaft on each floor. Thus the services are available in the shafts with a minimum of initial pipe installation and yet all pipes and valves are easily accessible to the maintenance personnel, and runouts can be made into any room without interfering with service in any other room.

A schematic diagram of this system is shown in Fig. 8, a plan of a service shaft is shown in Fig. 9, and Fig. 10 shows a photograph of the arrangement of vertical risers, take-off tees, valves, and runouts to a laboratory room. Pressure regulators and reducing connections can be mounted in the shafts when required. A diamond-plate steel fire stop is fitted around the pipes as a floor in the shaft space about 6 in. below the laboratory floor. This floor was lowered to accommodate a trap in the laboratory drain just above the floor. This arrangement allows the maximum possible vertical height in the service-strip pipe racks for normal pitch of all pipes (including the drain) for long runs around the laboratory room.

In general only those services needed in a particular room are taken beyond the valve in the shaft. However, a set of standardized service positions has been worked out as shown in Fig. 11. Those not needed are omitted.

Thus all standard service runout pipes can be prefabricated and slipped into place with minimum delay.

SERVICE STRIP

As was mentioned, the pipe services are carried around the walls of a laboratory room on a 6-in. wide pipe rack having a horizontal top called a service strip. In general, the outlets for all pipe services are mounted on the top of this strip. Laboratory furniture or equipment of any kind can be placed in front of this service strip which is mounted on the wall so as to be about ½ in. above the normal bench top. The furniture is therefore independent of the pipe services and can be moved or rearranged with ease, except that sinks and hoods must necessarily be "plumbed in."

Where no cabinets are to be placed in front of the service strip, the pipes can be covered by a snap-on steel panel painted the same color as the steel partitions and furnished by the same manufacturer.

The service strip may be extended at right angles to a wall with benches on one or both sides to provide a "peninsular" arrangement. As yet we have found no necessity for "island" benches with their pipes either in or through the floor.

ELECTRICAL DISTRIBUTION SYSTEM

Electrical energy for the project is furnished from 33-kv loop feeder of the New York Power & Light Cor Fig. 12 is a single-line diagram of the electrical distribution system. The outdoor substation initially contains a single 33-kv tap and circuit breaker but designed for future installation of another feeder an additional circuit breakers to provide loop service wit differential relaying to make possible service from on end only in case of trouble at the other end.

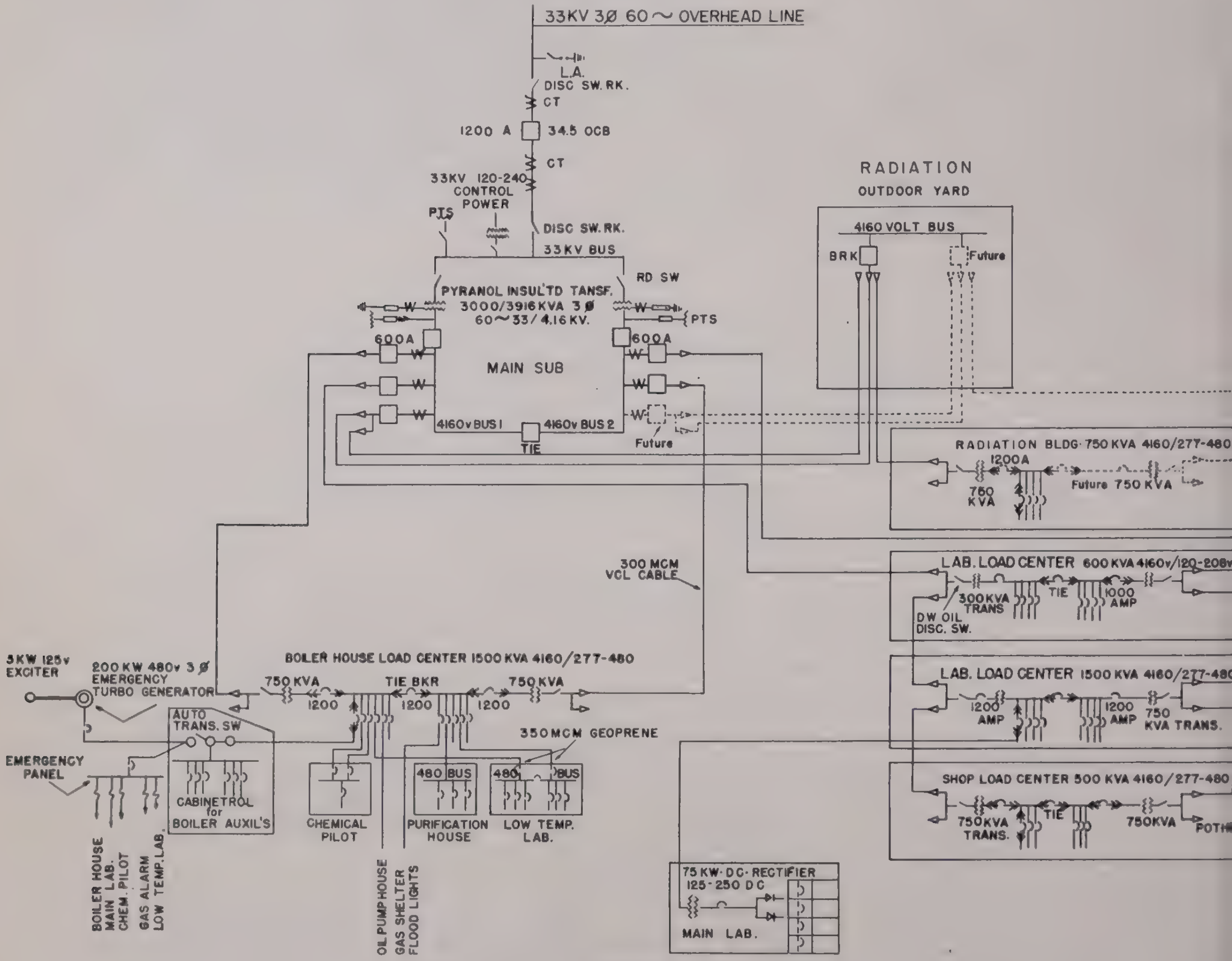


Fig. 12. Diagram of electrical distribution system

Switching operations at the outdoor substation a controlled from a duplex board in the electrical contr room in the basement of the main building.

The underground distribution voltage from the ou door substation is 4160 volts. A dual system of di tribution and secondary transformation is provided order to assure continuity of service.

Double-ended 1500-kva metal-clad load-center uni are provided at each of the following locations: (Main Building; (b) Shops; (c) Steam-generating st tion; and provisions are made for additional loa center units in future wings or additional building Secondary tie circuit breakers are provided at each loa center so that in emergency the loads can be connecte to one feeder system if the other is inoperative. This should provide excellent flexibility and reliability of service. Photographs of the duplex control board and a typical load-center unit are shown in FIGS. 13 and 14. Except for special lighting and research circuits, the general secondary distribution lines are 277/480-volt 3-phase 4-wire 60-cycle.

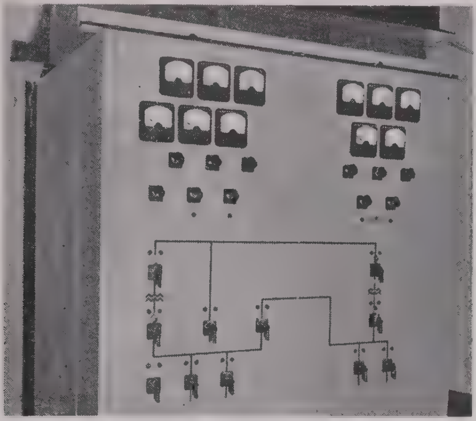


Fig. 13. Duplex board for remote control of the outdoor substation

HOP POWER AND LIGHT DISTRIBUTION

In the shop areas the secondary distribution lines are run as 4-bus, steel-encased Trumbull Electric Company's Flex-A-Power lines suspended from messenger cables under the beams. Fused plug takeoffs are used where needed for machine tools and for lighting feeders. The lighting units in the shop areas contain two 100-watt fluorescent lamps in open-ended reflectors with two-lamp 265-volt ballasts. These units are arranged in a checker-board pattern to give 30 to 35 foot-candles at the work surfaces. Small dry-type transformers are provided on individual machine tools to supply incandescent spot-light illumination where required.

ELECTRICAL SERVICE TO RESEARCH ROOMS

In all the main building's even-numbered shafts, three Flex-A-Power busways mounted vertically provide electrical service to all floors from interlocked-armor distribution cables on the second floor. One busway contains a 277/480-volt 3-phase 4-bus system for large power loads. At six locations on each floor, this busway is tapped to feed the fluorescent lighting system which has been described previously. Two-lamp 265-volt ballasts are used throughout. Another busway contains a 120/209-volt 3-phase 4-bus system for instrumentation and low-power use. The third busway contains a ±125/250-volt 3-bus d-c system fed from a 75-kw electronic rectifier in the electrical load-center room.

From the foregoing it will be noted that each system has its own neutral bus so that any one may be de-energized for repair without interfering with any of the others.

In addition, a bare copper cable is mounted in each electrical shaft to provide a protective grounding system to which the steel frame of the building, all steel partitions, and the frames of pieces of experimental apparatus can be connected. This grounding system is connected to a series of copper rods driven into the earth under the center corridor of the building before the concrete floor was poured. It is also bonded to the incoming city water pipes.

ELECTRICAL SERVICE IN RESEARCH ROOMS

When any one of the electrical services is desired in a research room, a standard plug connection is made in the corresponding riser in the nearest electrical shaft. This plug contains a 70-amp quick-acting thermo-magnetic-trip circuit breaker. From this plug a cable connection is made to a miniature steel-clad Flex-A-Strip bus system which has been developed by the

g. 14. One of three double-ended 00-kva load-center units for provid-
g power and light

Trumbull Electric Co. specifically for the distribution of electric circuits along the walls of research laboratory rooms. The runs are made up from interchangeable sections of various lengths which can be carried in stock and assembled as desired.

Fused outlet boxes, also factory built and carried in stock, can be inserted in place of sections of Flex-A-Strip to give the number of service outlets required. As with the pipe services, the desire for standardization to give minimum initial cost has led to the arrangement shown in Fig. 1 for use in most research rooms. The sub fuses in the outlet boxes allow the experimenter to protect particular pieces of apparatus with cartridges having fusing values from a fraction of an ampere to 20 amp as desired.

The principal advantage of the Flex-A-Strip system is its flexibility since it is made up of "take-apartable" units which can be factory made, carried in stock, quickly assembled or disassembled as room occupancy changes. Furthermore, it offers a higher level of electric service (70 to 100 amp per bus) than is usually obtained in conventional conduit wiring. The outlet-box sections may be either standard boxes or blank boxes that may have installed in them any special receptacles or small magnetic breakers needed for a particular experimental setup.

TYPICAL PHYSICAL AND CHEMICAL LABORATORIES

The need has already been indicated for standardization of pipe and electric service outlets in laboratory rooms in order to allow prefabrication of parts and to minimize an admittedly large item of cost in a research laboratory building. Insofar as practicable, furniture layouts in research rooms were also standardized; for example, Fig. 15 shows typical physics and electronics room arrangements. It will be noticed that the workers' desks are in the most desirable location by the windows and that the work spaces and service strips grow out from the shafts along the corridor, thus giving minimum length of service runs. There are no "island" benches and no holes in the floors except in the service shafts.

Although the present structure will provide principally for work in physics and metallurgy, all service facilities are so designed that the space can be used

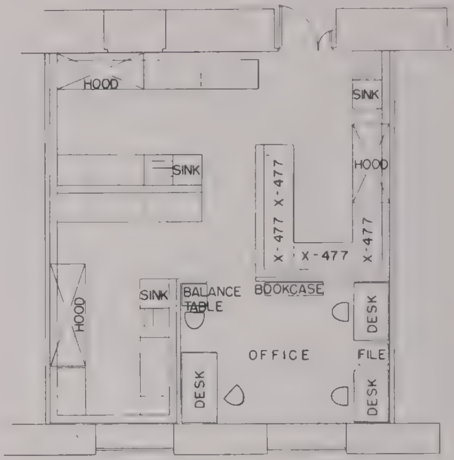


Fig. 16. Typical three-man organic chemistry laboratory

also for chemical research. A typical arrangement fo pipe-service strip and furniture for a three-man organi chemistry laboratory is shown in Fig. 16. This i practically the same layout as that used in the experimental room (Fig. 7). Three independent workers have a common glass-enclosed office by the windows and each has his individual work space comprising a sink hood, bench, and cabinet space arranged to requir minimum footsteps to reach any work area. Each individual has all the advantages of working in space used only by him without the psychological disadvantages of working alone. A poll of our chemical experimenters showed that 80 per cent desired this type o working arrangement.

AIR SUPPLY

Ventilation air (six changes per hour) is supplied t all windowless spaces such as interior offices and dark-

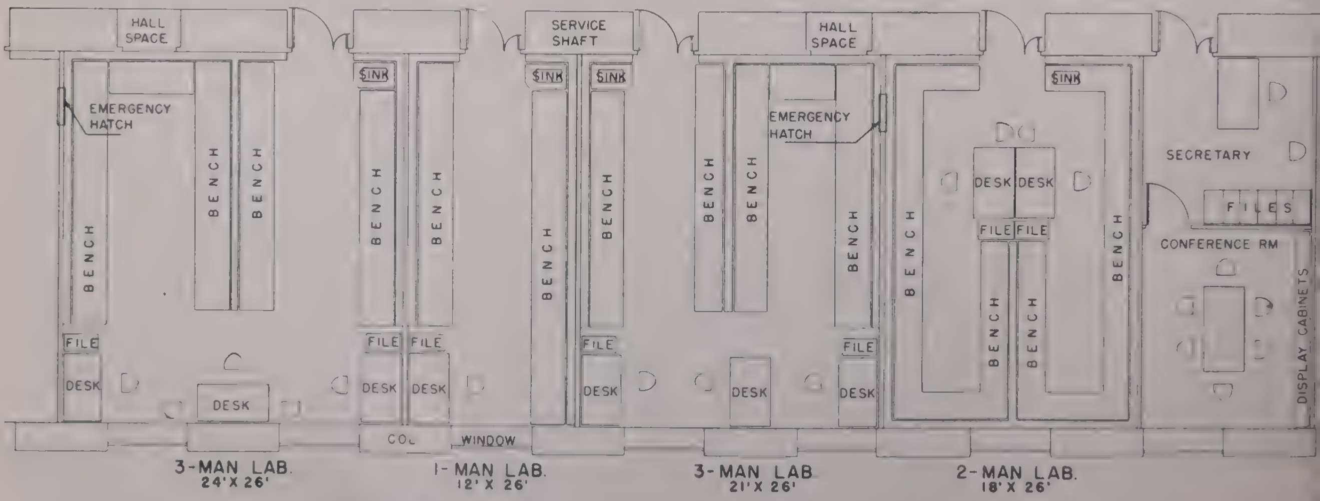


Fig. 15. Typical physics and electronics room arrangement

rooms. Also about 750 cfm must be exhausted from each chemical hood, of which about ten are requested for three floors in the present occupancy plan.

The air intake is through an aluminum grill at the side of the building's front entrance. The intake fan and 'Oilomatic" filter are located in the basement, and about 8000 cfm of ventilation air is supplied to the corridor of each floor. All corridor doors into research rooms are provided with louvers so that air exhausted from the rooms will be drawn from the corridor.

AIR EXHAUST

The north third of each vertical shaft contains about two square feet of space reserved for vertical air ducts.

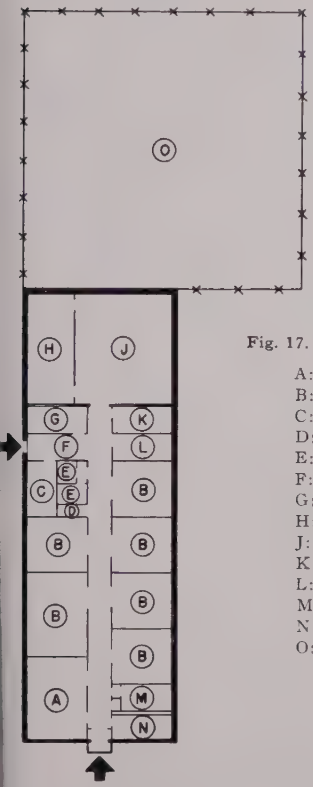


Fig. 17. Floor plan of Radiation Laboratory

A: Office and Conference Room
B: Laboratory
C: Drafting Room
D: Stairs
E: Dark Room
F: Corridor
G: Control Room
H: Pit
J: Synchrotron
K: Stock Room
L: Machine Shop
M: Women
N: Men
O: Outdoor Electrical Equipment

All windowless spaces in the building are provided with ucts to exhaust the required amount of ventilation air. The air from such spaces and all hoods is exhausted irectly to a collecting duct in the monitor above the fth floor and then blown vertically upward from the uilding by exhaust fans.

Likewise all windowless spaces in the shops are proided with ventilation-air intake filters, blowers, and xhaust blowers. Special rooms such as the wood shop, lass shop, and paint-spray booth have their own pecial exhaust systems. In general, the requirements or ventilation air are such that the air cannot be ecirculated.

CCUPANCY STUDIES

The most time-consuming function of the planning roup has been the arrangement of partitions, service runouts, and furniture so as to satisfy the needs of the occupants of the research space. More than 4000 manhours have been spent by planning personnel in such studies without counting time spent by the technical people themselves in sketching their requirements.

Such studies are inevitable unless the occupants are to be forced to accommodate themselves to arbitrarily determined standard room and furniture arrangements. Considering the great variety of work being done by our scientists, such standardization would be uneconomical, if not impossible, and directly opposed to the idea of flexibility which was our first stated objective. Nevertheless a degree of standardization has been achieved in the positioning of service outlets to allow considerable prefabrication of service runouts.

RADIATION LABORATORY

The Research Laboratory has long been noted for its contributions in the development of high-voltage x-ray and electron-accelerating devices. Experimentation with large betatrons, synchrotrons, and associated apparatus requires heavy floors, special shielding, wide doors, and high headroom and therefore cannot be housed conveniently in the main building.

The small building for which a floor plan is shown in Fig. 17 was designed specifically for that type of experimentation. It requires normal laboratory services plus large quantities of high-voltage electric power. Necessary heavy electric equipment has been designed for outdoor installation to the north of the accelerator room. A 10-ft-wide corridor and large sliding doors are provided between the accelerator room and the experimental work rooms so that heavy apparatus of many types can be developed and assembled in these rooms and then taken to the accelerator room in specially designed multiwheeled trucks.

Under the central corridor is a basement pipe gallery from which all service pipes can be run to all research rooms through slots in the floor at 12-ft intervals along the room sides of the corridor partitions. The services will then extend in service strips along the cross partitions as in the main building.

LOW-TEMPERATURE LABORATORY

The work to be done in the Low Temperature Laboratory may be somewhat hazardous since it involves the liquefaction of hydrogen and helium necessary for experimentation at temperatures approaching absolute zero. The necessary equipment and experimental space have been housed in a small specially designed building located on the lower level near the river bank. Fig. 18 shows a floor plan of this building. The liquefaction rooms are separated from the remainder of the building by reinforced concrete walls to guard against injury in the remote possibility of an explosion.

All normal services are brought to this building

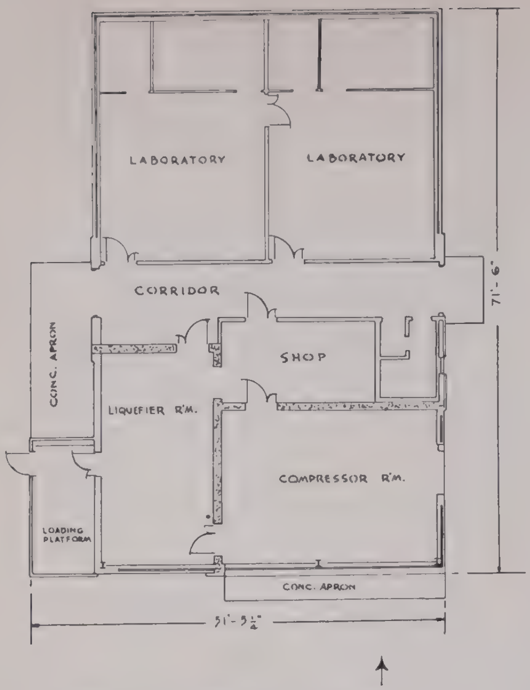


Fig. 18. Floor plan of Low Temperature Laboratory

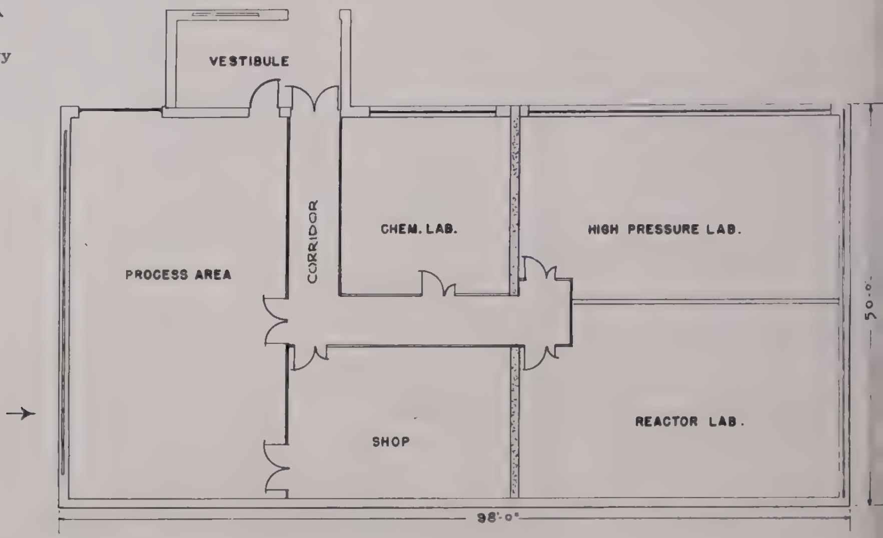


Fig. 19. Floor plan of Chemical Pilot Plant

underground and the pipes are either buried in the concrete floor or run exposed overhead, depending on the location. Large quantities of hydrogen will be used in this work and a direct underground connection is provided to the hydrogen trailer manifold.

CHEMICAL PILOT PLANT

Fig. 19 shows a floor plan of the Chemical Pilot Plant designed for larger-scale chemical development and experimentation which cannot be housed adequately in standard laboratory space. Autoclaves are placed behind steel barriers in rooms with scored windows separated from the remainder of the laboratory by reinforced concrete walls. In another area 20-ft headroom space is provided to facilitate the use of tall separation and reactor columns. Also the building is designed so that the height of this room can be increased to 60 ft if desired later. Steel grating floors may be installed in this room at elevation intervals of 10 ft, if required, to provide access at various heights to such columns.

CONCLUSION

Into the design of these buildings has gone the accumulated experience of over 48 years of fundamental research in industry. Recognizing the ever-changing needs of scientific exploration, it is our hope that these exceptionally flexible and adaptable buildings and services will provide the most efficient possible facility for scientific research.

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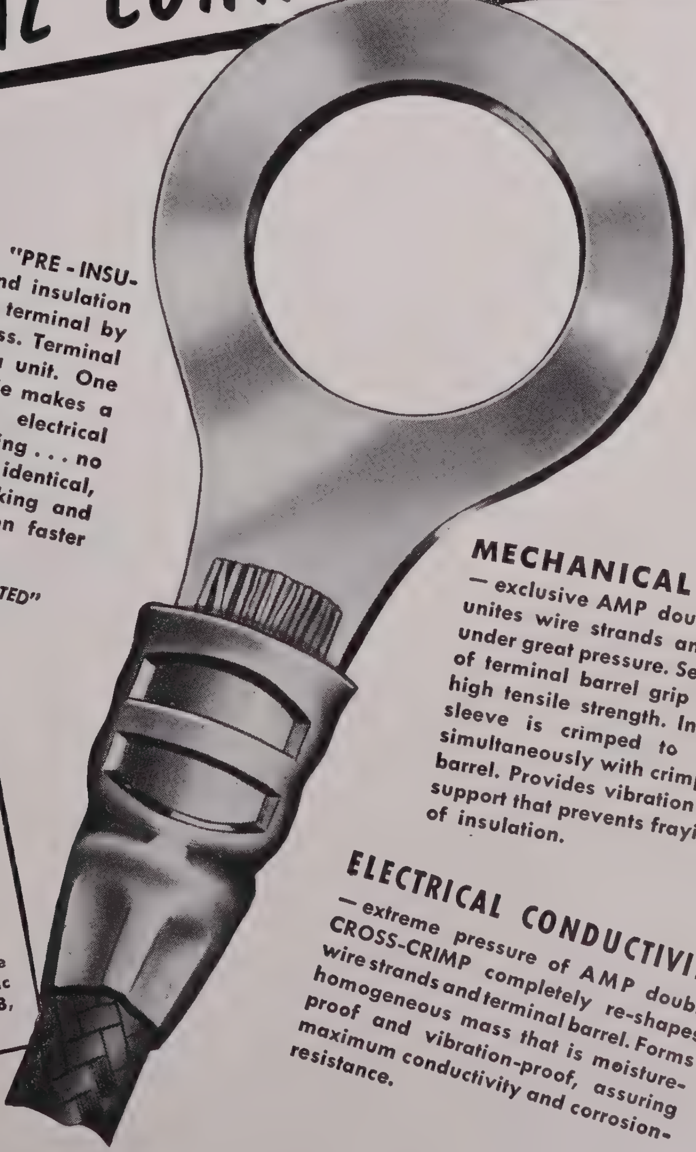

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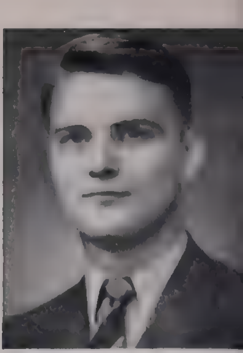
NEW TECHNIQUES IN MEASUREMENT OF MAGNETOSTRICTION



J. K. Mickelsen

The presence of marked magnetostriction characteristics, producing useful ultrasonic vibrations as well as some undesirable effects, now requires increasing attention

By J. K. MICKELSEN
General Engineering and Consulting Laboratory
General Electric Company

MAGNETOSTRICTION, the phenomenon involving the realignment of aggregations of molecules and a consequent change in dimensions when certain materials are placed in a magnetic field, can be useful or undesirable according to circumstances.

On the one hand, it is possible with materials having marked magnetostriction characteristics to produce useful ultrasonic vibrations by rapid changes in the applied magnetic field. This phenomenon is utilized in the construction of magnetostriction oscillators, and also in magnetostriction transducers(1) for converting alternating current to high-frequency sound waves in water.(2) On the other hand, changes in magnetic field inherent in the operation of motors, generators, transformers, and other electric equipment often produce a magnetostriction effect which results in undesirable operating noise. The study of magnetostriction, therefore, has been receiving increasing attention of late, and several new measuring techniques have been developed.

In the past it has been the usual practice to measure magnetostriction effect by using direct current to create the magnetic field. The assumption was then made that a curve of the magnetostriction effect produced by an alternating current could be plotted as an appropriate series of individual values of strain produced by different values of direct current, to show the instantaneous effects of an alternating magnetic field. That assumption could not be verified, however, until equipment for measuring a-c magnetostriction phenomena had been designed and built.

The Joule effect,(2) or elongation of the specimen, is of greatest interest. To measure these small strains, seldom larger than 40×10^{-6} in./in., some means of magnification or amplification of the magnetostriction strain is needed. This is often achieved by optical or a combination of optical and mechanical methods.(3)(4)(5) When a-c excitation is used, however, difficulties may result from mechanical magnification caused by mechanical resonance of the levers. Because of the inertia and elasticity of these lever arms it is not always possible to obtain a simple direct relationship between the a-c magnetostriction and the resultant time-varying output.

These difficulties are overcome in the magnetostriction testing apparatus recently developed in the General Engineering and Consulting Laboratory. This equipment, shown in Fig. 1, can be used with either a-c or d-c.

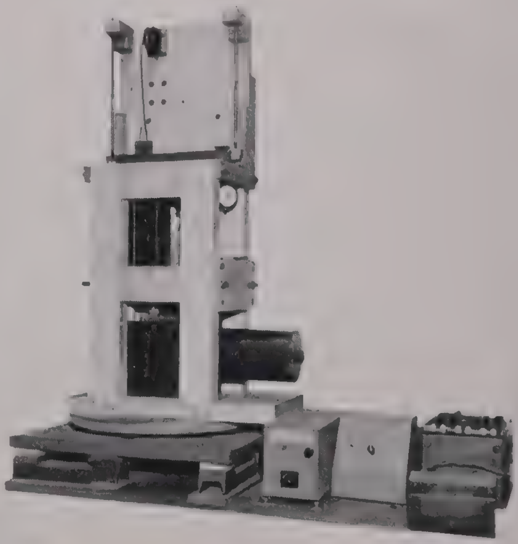


Fig. 1. Magnetostriction testing apparatus

In this apparatus, a test specimen is placed inside magnetic coil in such a position that expansion of the specimen produces displacement of one of two optica gratings in a specially arranged optical system, as shown in Fig. 2. The optical system includes a light source, collimating lens, one fixed optical grating, the movable grating already mentioned, a converging lens, and an output phototube. With this arrangement the amount of light falling on the phototube is reduced in proportion to the displacement of the movable grating.

The movable optical grating is firmly attached to the lower end of the test specimen. Thus the grating is displaced directly with the specimen elongations minimizing the mechanical-resonance conditions. The weight of the optical grating and its supporting structure, on the test specimen, is about two pounds. For a specimen of 0.014 in. by 3 cm. cross section, this is equivalent to a tensile stress of 150 lb/sq in. (1/1

This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—Editor

(1)Numbered references are listed at the end of the article.

g/mm^2). Tests have proved that this stress has negligi-le effect on magnetostriction measurement of ordinary nagnetic materials.

OMPENSATING TECHNIQUES

Compensation for temperature changes is accom-lished by the use of a dummy specimen connected to he so-called fixed grating. Ambient-temperature varia-ions affect test and dummy specimens equally, pro-lucing no relative motion of the two gratings. The eating of the test specimen, caused by power loss in he magnetizing coil, is counterbalanced by a non-nductively wound coil(3) which heats the dummy pecimen equally during the d-c tests. In the a-c tests he test specimen is heated more than the dummy by ddy current and hysteresis losses. Here interest enters in the alternating voltage caused by the agnetostriction of the specimen excited by the a-c eld, rather than in the slowly changing voltage aused by the unequal heating and expansion of the pecimens. Consequently a series capacitor is included the output circuit to permit only the alternating utput component to be amplified and measured.

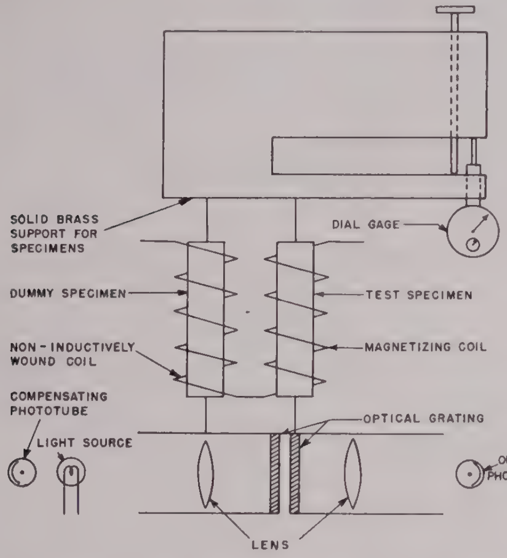


Fig. 2. Diagram showing basic components of the magnetostriction testing apparatus

The light received by the output phototube depends n the output of the light source as well as the relative ating displacement. A compensating phototube, ceiving light directly from the lamp, is therefore nnected to the output circuit, and the resultant out-ut is thus made independent of small light-level ariations caused by lamp voltage changes. By varia-on of the lamp light level over a large range, the nsitivity is changed to fit test requirements.

BRATION

Measurement of a-c magnetostriction involves the e of a highly sensitive detecting element. Because of is sensitivity, unwanted vibrations could easily be corded and give erroneous results. One way in which these unwanted vibrations might reach the magnetostriction testing apparatus is by transmission through the building in which the equipment is located. They are prevented from reaching the apparatus, however, by mounting it upon a heavy base supported by rubber blocks and lever arms (as in FIG. 1), which gives it a natural frequency of about four cycles per second.

Unwanted vibrations could arise from possible modes of vibration of the test specimen. This danger is minimized by the addition of clamps, which will be mentioned later.

One of the most troublesome problems encountered in the design and construction of the magnetostriction testing apparatus was in minimizing or eliminating mechanical resonances in the apparatus and test specimen. This consideration strongly suggests that much of the noise produced by electric machinery may be due to resonance vibration excited by the a-c magnetostriction effect in the magnetic materials.

SPECIMEN HOLDER

The test specimens are single strips, 3 cm by 28 cm, cut from sheets of the material to be tested. The magnetostriction tests can be readily related to other magnetic test results, since these specimens are of the standard Epstein Test size.(6)

To obtain an accurate relationship between specimen induction and magnetostriction, the magnetostriction must be measured over the region of uniform induction. This is accomplished, as shown in FIG. 3, by so clamping the specimen that the magnetostriction is measured over the central four inches of the specimen. Since that portion of the specimen is centrally located within the solenoid, it is a region of very nearly uniform magnetization.

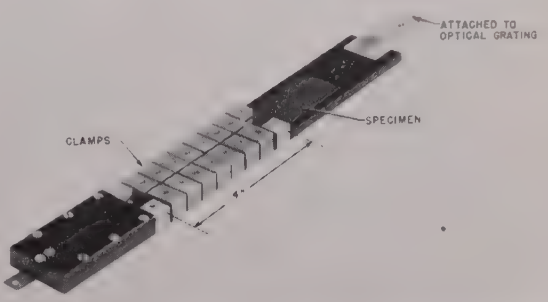


Fig. 3. Test specimen clamped in place in the specimen holder

The additional brass clamps placed on the central portion of the specimen raise the natural mechanical frequency of the specimen above test ranges and minimize undesirable resonant frequencies.

CALIBRATION

Calibration for the d-c tests is made possible by the special shape of the solid brass block supporting the specimens (see FIG. 2). The lower portion of the block, from which the test specimen is hung, acts as a cantilever beam. By deflecting the free end of the beam, a smaller displacement of the test specimen and its attached optical grating is produced. The deflection of the free end of the beam is measured by a dial gage whose smallest divisions indicate 0.0001 in. deflection. Calculations and measurement show that the test specimen displaces about 1/70 of the deflection measured by the dial gage. The amplified output-phototube current variations are thus related to the small, accurately known specimen displacements. This calibration makes it possible to distinguish between positive magnetostriction, which ordinarily occurs in electrical sheet steels, and negative magnetostriction, which occurs in nickel.

At present the a-c test data are relative only, because periodic motion of small but accurately known amplitude of the test specimen has not been produced. When this difficulty is overcome, satisfactory calibration for the a-c tests will be achieved.

ALTERNATING-CURRENT PERFORMANCE

The current variations of the output phototube are amplified and then read by a flux voltmeter.(7) As previously mentioned, the a-c test results are relative only. These test data are useful in that they make it possible to compare various test specimens. An accuracy of ±20 percent is indicated by repeated tests on a specimen for identical conditions of induction and frequency.

ALTERNATING-CURRENT TESTS

The flux voltmeter is used to measure the amplified output because its reading is proportional to the peak magnetostriction strain. The test data are usually obtained by determining the flux voltmeter reading at each desired frequency of magnetizing current. The magnetizing current is held constant, thus keeping the specimen induction constant. Such test results for typical transformer steel will look much as shown in Fig. 4. If desired, the frequency can be held constant while the specimen induction is varied. When this is done, a curve similar to that in Fig. 5 will result for such material. As is seen in Fig. 4, the peak magnetostriction for constant peak induction is independent of frequency, within the limits of measurement error. Results indicate that d-c curves such as are shown in Fig. 6 can be used, at least for the lower power frequencies, to relate instantaneous values of magnetostriction and induction.

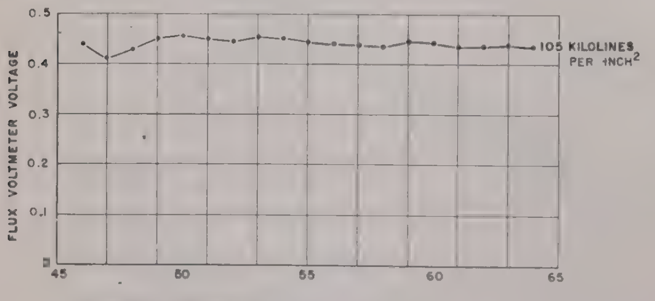


Fig. 4. Typical a-c magnetostriction test results on transformer steel while the magnetizing induction is held constant

DIRECT-CURRENT PERFORMANCE

The usual d-c test can be made for all values c magnetostriction from 0 to 100×10^{-6} in./in. with a error of ±10 per cent or 0.2×10^{-6} in./in., whichever i the greater. Relative grating displacements of $0.2\times$ 10^{-6} in. have been detected, corresponding to a magnetostriction strain of 0.05×10^{-6} in./in. For these tests the current change of the output phototube is measure with an electronic microammeter.

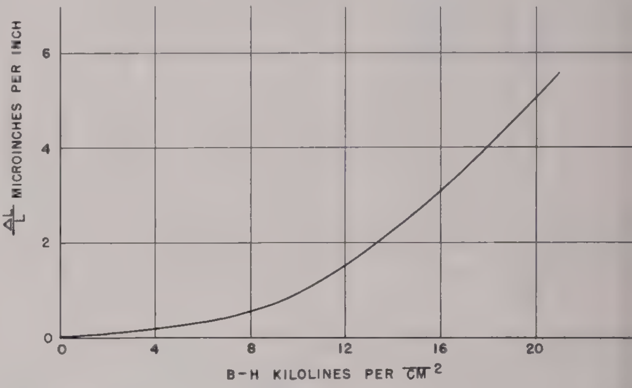


Fig. 5. Typical d-c magnetostriction test results on transformer steel. The curve resembles that of a-c magnetostriction at constant frequency

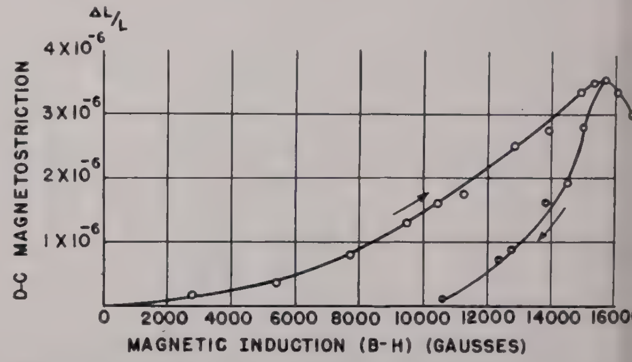


Fig. 6. D-c magnetostriction test showing hysteresis effect in standard sheet steel

DIRECT-CURRENT TESTS

The d-c test consists in measuring the magnetostriction performance of a test specimen placed in a d- magnetizing field. After the specimen is properl mounted, the calibration data are obtained. When th specimen has been demagnetized, it is remagnetized t the desired induction by the use of a preset magnetizin current. With reference to the change in output curren caused by remagnetizing the specimen, the magnetostriction strain is calculated from the calibration data This process is repeated for other points until th desired test range has been covered. Representativ test results on a high grade of transformer steel stri are shown in Fig. 5.

The current through the magnetizing coil can b varied to cause the specimen induction to go through ysteresis loop, resulting in performance similar to hat shown in FIG. 6.

The relationship between the specimen induction and magnetizing current is obtained on each specimen vhile it is mounted in the magnetostriction testing apparatus. These data are needed for both a-c and d-c ests.

CONCLUSION

Magnetostriction has been useful or detrimental in the past, according to the circumstances. The development of new equipment and techniques to measure a-c magnetostriction provides the tool for better control of the harmful effects of magnetostriction. The new knowledge also affords opportunity to uncover additional beneficial uses for this phenomenon.

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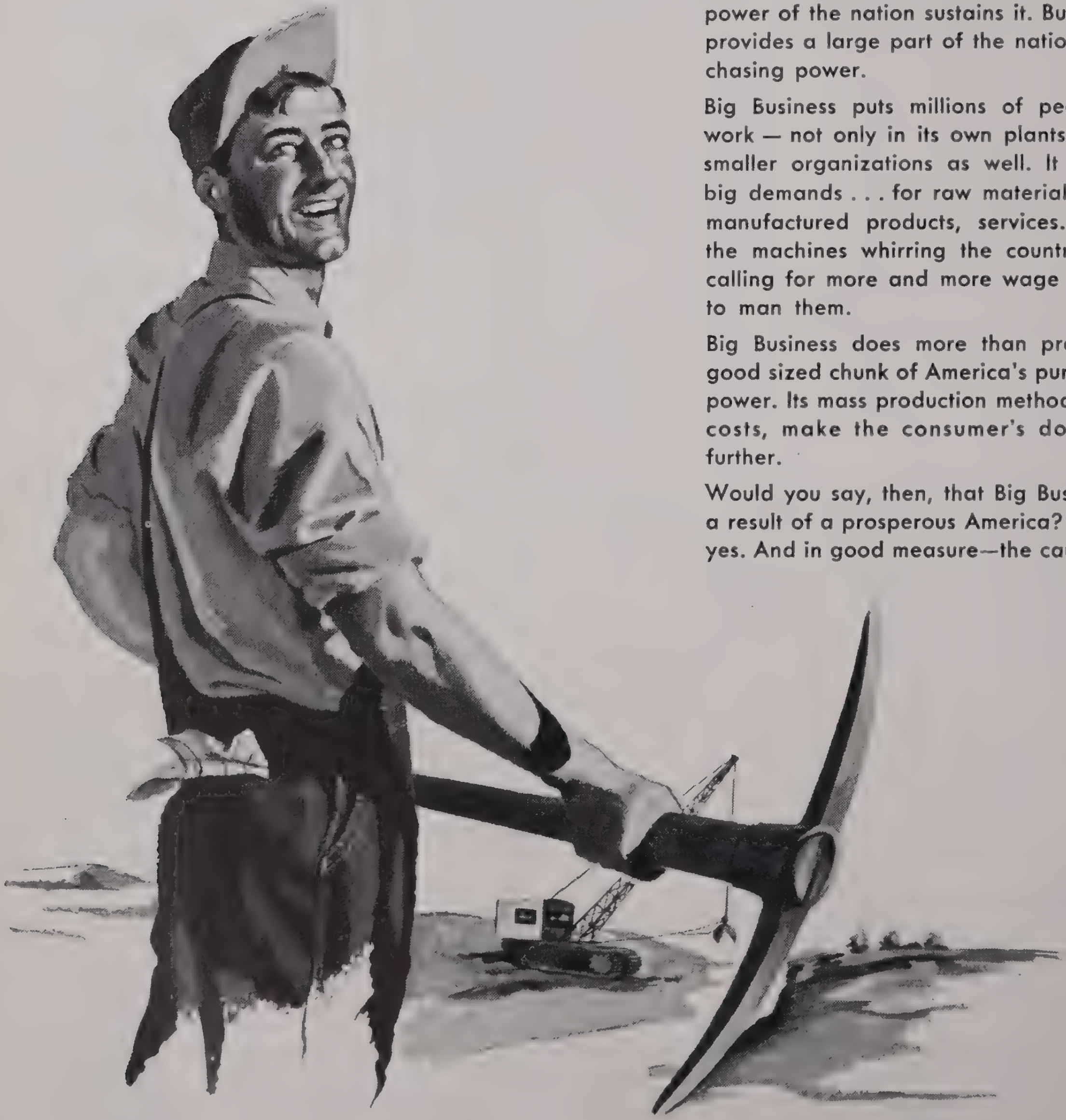

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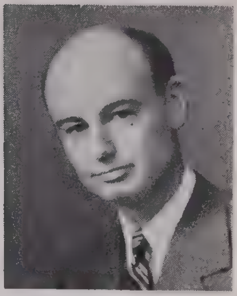
PROTECTIVE ATMOSPHERES IN INDUSTRY . . . Part I

Allen G. Hotchkiss

They reduce costs, improve quality, and speed production of many and different products. How and where they are utilized and for what purposes. Typical examples

By A. G. HOTCHKISS and H. M. WEBBER
Industrial Heating Divisions, General Electric Company



H. M. Webber

PROTECTIVE atmospheres in industry are saving money, improving quality, and speeding production. Furnaces with protective atmospheres, for example, turn out work free from oxides or scale, which saves metal and eliminates cleaning operations, such as pickling. In the paint and varnish industry protective atmospheres prevent oxidation in storage, eliminate skins on paint and varnish in tanks and pipe lines, replace carbon dioxide for "blowing" synthetic resins, and provide a good means for extinguishing fires.

Further advantages of those and other applications of protective atmospheres in industry will be elaborated upon in this present series of articles in which there also will be information concerning: How and where to apply the most common commercially available gases for atmospheres; theoretical considerations regarding reactions; properties of commercially available atmospheres—their costs, methods of manufacture, and supply; how to handle gases with safety and economy; and remedies for furnace-atmosphere ailments.

The foregoing topics indicate that proper applications require knowledge and experience with respect to the gases and the processes for which they are to be employed; also that proper operation of the equipment is essential after installation. Fortunately, these necessities are all well within the grasp of both atmosphere-equipment manufacturers and users; and, as a result, protective atmospheres are enjoying rather wide application.

PROTECTIVE ATMOSPHERES FOR FURNACES

Not many years ago, most heat-treating furnaces were made with loosely constructed jackets of steel or brick and with loosely fitting doors, with no great thought given to the atmosphere in which the work was heated. Heavy scaling of the parts being treated was considered a necessary evil. Electric furnaces had air atmospheres, and open-fired gas furnaces had atmospheres consisting of the products of combustion. Operators of the gas furnaces found that they could slightly reduce the scaling by controlling the air-fuel mixture to the burners but this gave inefficient heating, and the results with respect to oxidation were still inadequate.

Today, however, thousands of furnaces used in numerous processes turn out ferrous and nonferrous materials shiny-bright, or at least clean and free from scale, commonly with surface conditions equal to, or better than, before the parts enter the furnace.

This change was brought about by the use of protective atmospheres in the furnaces, accompanied by important changes in furnace construction. Such changes included the use of gastight steel casings and tighter doors and other outlets or inlets for gas or air. In most electric furnaces, the protective atmosphere is maintained within the heating chamber in such a manner that it protects both the work and the heating units, the latter radiating heat directly to the work. In some electric furnaces, however, and in all gas-heated furnaces, the protective atmosphere surrounding the work is separated from the heat source by means of a retort, or alternatively in many gas furnaces by confining the flames within alloy tubes which radiate heat to the work. In each instance, these protective atmospheres are gases (or, more commonly, combinations of gases), which are used to displace the air in the heating chamber and in the cooling chamber, if there is one, to prevent or minimize changes on the surfaces of the work being treated.

TYPES OF SURFACE CHANGES

Oxidation

There are two principal types of surface changes commonly encountered on metals heated in furnaces. The most common type is oxidation, which is the result of oxygen in some form combining with the metal. The oxide thus produced may range from a thin tight discoloration to a thick loose scale. By using a protective atmosphere in the furnace to eliminate surface oxidation, cleaning methods such as pickling or sand blasting are unnecessary after heat treatment, which results in cost savings, better quality, and shorter manufacturing cycles.

Metallurgical

The second type of surface change might be called a metallurgical change because it relates to the reaction of the gases with the metal surfaces in such a manner

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This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

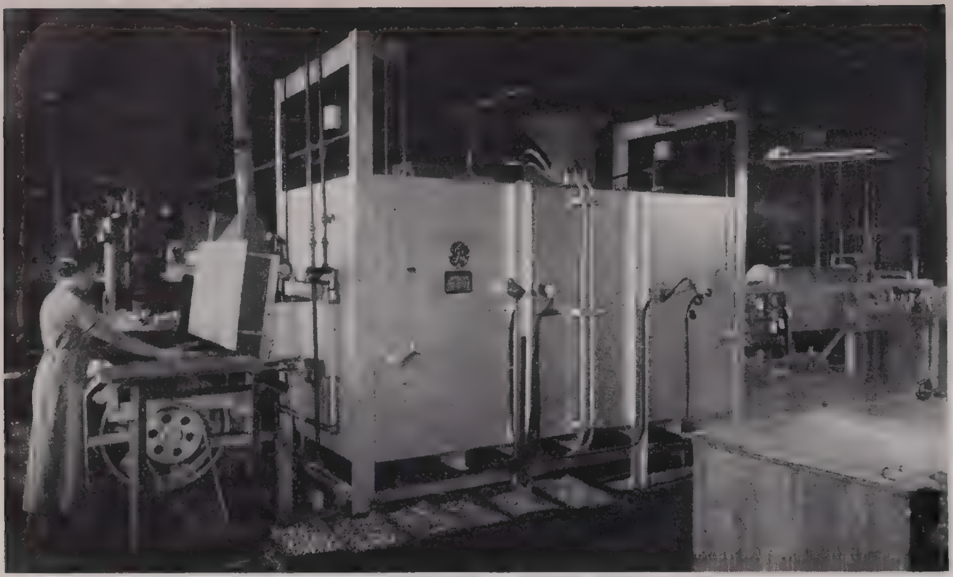

Fig. 1. A typical mesh-belt conveyor type electric furnace which uniformly an brightly anneals stampings, such as radi and refrigerator parts. Because these part emerge free from scale, pickling is com pletely eliminated

as to add carbon to the surface of low-carbon steels (called carburizing) or to remove carbon from the surface of high-carbon steels (called decarburization). By eliminating decarburization through the use of protective atmospheres, high-carbon steel parts after heat treatment are hard at the surface instead of having a soft skin. As a consequence, they have good wear resistance and high strength without requiring machining or grinding to get down to hard metal. Thus, use of protective atmospheres also reduces costs, improves quality, and speeds production.

Other applications under this second classification are gas carburizing, which involves the forming of high-carbon surfaces on low-carbon parts for case-hardening; carbon restoration to surfaces of medium- or high-carbon steels previously decarburized in mill operations, thus producing a hard surface after subsequent heat treatment; and nitriding, which gives extremely hard surfaces to special types of steels when subjected to an ammonia atmosphere at about 1000 F.

PROTECTIVE ATMOSPHERES FOR GENERAL INDUSTRIAL APPLICATIONS

There are numerous instances where protective atmospheres originally developed for use in furnaces have been applied successfully to other industrial applications. In most of these instances, the new atmospheres have been applied to replace other atmospheres which were more expensive; or, because of their low cost, they could be applied where the use of more expensive atmospheres was prohibitive. In either case, the objective is to save money; but there are often other advantages, including improved quality, better continuity of service, less maintenance, and greater safety.

Inert Atmospheres

Here again, we have two general types of atmospheres with respect to results on the products with which they are employed; for example, there are the inert atmospheres, which have neither oxidizing nor reducing characteristics. The nonoxidizing feature is responsible for success in the paint and varnish industry in eliminating oxidation of the various materials treated, and in extinguishing fires. Some rubber tire manufacturers have found the nonoxidizing gas gives considerably longer life to heated rubber bags, previously filled partly with air during the tire-curing treatment. In the food industry, nonoxidizing gases help preserve the vitamins and flavor of canned fruit juices. In the drug and chemical industries, as well as others, certain finely powdered materials or dusts offer explosion hazards when they are mixed with air, in which cases inert atmospheres provide greater safety in the handling of them.

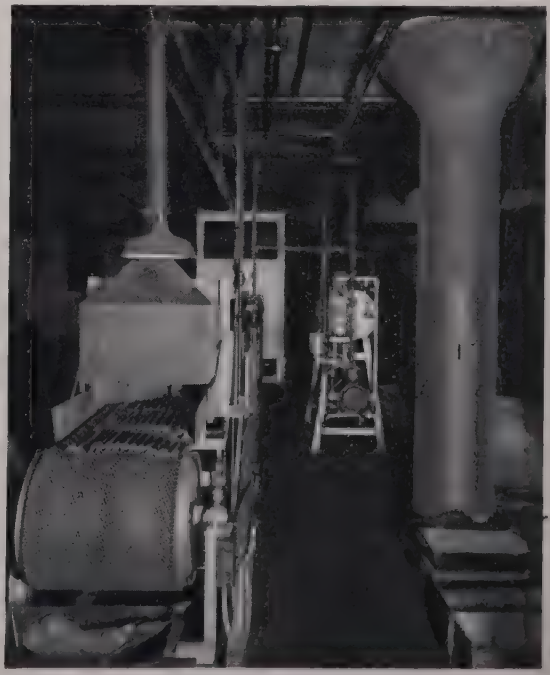

Fig. 2. Discharge end of mesh-belt conveyor-type electric furnace shown in Fig. 1. Bright-annealed stampings are emerging from the cooling chamber and dropping into a tote box

Reducing Atmospheres

The second type of atmosphere is that having highly reducing properties because of its high hydrogen content. For example, a low-cost substitute for hydrogen—dissociated ammonia—reduces cost and gives excellent results in the sodium hydride descaling process (the new method of removing scale from stainless and alloy steels); in atomic hydrogen arc welding, in which the arc between tungsten electrodes and the puddle of molten weld metal are enveloped in a protective shield of hydrogen; and in the hydrogenation of oils, fats, lards, and other materials, in which the materials are treated with hydrogen under pressure and heat, to change their characteristics.

The use of hydrogen-nitrogen mixtures in the form of dissociated ammonia, as a low-cost substitute for hydrogen, has enhanced the attractiveness of these and other processes through increased profits and sometimes other advantages.

SUCCESSFUL APPLICATIONS OF PROTECTIVE ATMOSPHERES

Information on how and where to apply protective atmospheres in industry will appear later in another part of this serial, after the atmospheres themselves have been thoroughly considered. A few typical examples are included here in Part I, however, to highlight the advantages of using protective atmospheres and to serve partially as illustrations for Tables I and II.

Bright Annealing

There is a wide variety of applications of protective atmospheres in furnaces for bright annealing. Typical of these is the use of a mesh-belt conveyor-type furnace, such as shown in Figs. 1 and 2, for annealing stampings between successive stamping operations. Representative parts so treated are nameplates, radio dials, refrigerator hardware, emblems, and drawn shells for miscellaneous uses. Such parts, formerly annealed in oxidizing atmospheres, were scaled and had to be pickled before they could be restamped. Because these parts now come from the furnaces clean and bright, pickling operations and their attendant costs have been completely eliminated. Incidentally, the uniform anneal from electric furnaces, because of the excellent temperature distribution, minimizes rejections and wear-and-tear on dies, and results in clearer-cut impressions from the dies.

Scale-free Hardening

Parts made on high-speed machines, such as punch presses and automatic screw-machines, are now scale-free hardened to good advantage in protective atmospheres. A typical belt-conveyor-type furnace for this class of work is shown in Fig. 3. Parts which formerly scaled in ordinary atmospheres, now, when treated in this type equipment, remain practically as clean and bright when they emerge from the quenching oil as when charged into the furnace. This results in important savings due to the elimination of scale removal, reduction of handling expense, and fewer rejects because of greater uniformity of the product from the electric furnace. Typical items heat-treated in conveyor-type scale-free hardening furnaces are: stamped typewriter parts; machined drill-chuck parts, such as sleeves, jaws, and keys; alloy-steel cap screws; and a miscellaneous assortment of gears, pinions, splines, and other finished-machined parts.

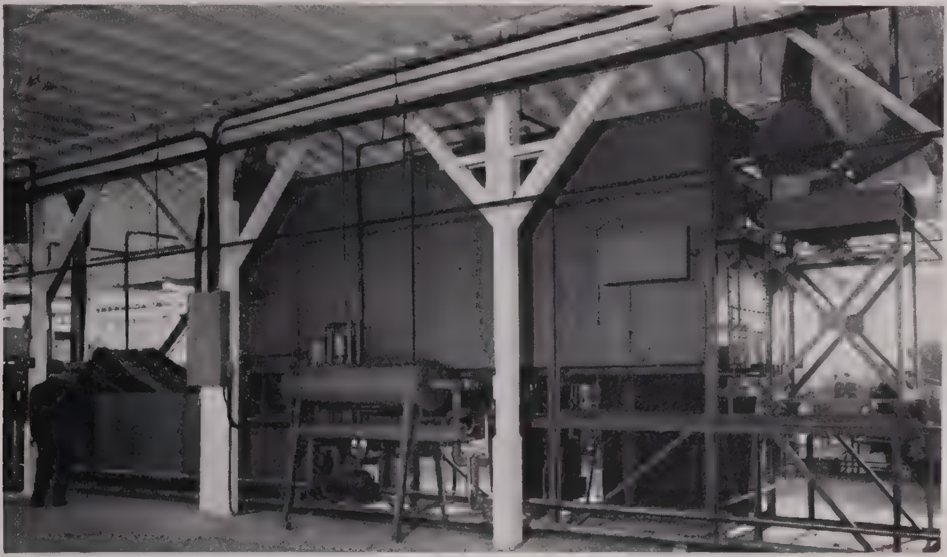

Fig. 3. Numerous varieties of finish-machined parts heat-treated in a conveyor-type scale-free hardening electric furnace, such as that shown here, emerge as clean and bright as when charged into the furnace

Such work is prevented from being oxidized in the furnace atmosphere. Also, it is prevented from being decarburized, where required, through selection of the proper atmosphere needed to retain carbon in the surface of the medium- and high-carbon steel parts.

Electric-furnace Brazing

The success of electric-furnace brazing—the modern fabricating method for metal parts—is almost entirely dependent on protective atmospheres, because the atmospheres prevent oxidation of the assemblies being heated and cooled in the furnace, and in most cases thereby eliminate the need of a solvent flux to encourage wetting and bonding of the parent metals by the brazing metals. Thus, the assemblies come from the furnaces without oxides and flux deposits, and they are immaculately clean and bright.

Numerous successful applications of the process include conversions in design from forgings, castings, and machined parts to fabricated assemblies consisting of stampings, screw-machine parts, and pieces of tubing. Typical of these is an automobile clutch hub, formerly forged and machined in one piece, now made from a punched-steel flange and a machined-steel hub, with a copper-wire ring placed over the hub at the joint and brazed in a box-type furnace similar to that shown in Fig. 4. Due to the saving in the original metal cost, and elimination of certain machining operations, the over-all cost reduction is reported to be 15¢ per hub, or $27 per furnace-operating hour, or $648 per 24-hour day, from a small 50-kw box-type furnace.

Powder Metallurgy

An old art receiving new recognition, partially because of the development of protective atmospheres, is that called powder metallurgy. Steadily broadening applications involve protective atmosphere furnaces for annealing and reducing powders during their manufacture, and for sintering pressed-powder compacts to form the final product.

Highly reducing atmospheres of hydrogen or dissociated ammonia are commonly employed for the annealing and reduction operations on powders, such as copper and iron, and for sintering of more particular metals, such as tungsten, molybdenum, alnico magnets, and stainless steels. Somewhat less reducing atmospheres are used for sintering iron bearings, gears, etc., and only slightly reducing or inert atmospheres ar used for sintering copper-tin-graphite bronze bearings cams, and similar parts.

A typical sintering furnace is that of the roller hearth conveyor type shown in Fig. 5 with a trayloa of representative bearings made of bronze or iron leav ing the discharging door. Such parts made by powde metallurgy are accurately sized with no machinin operations required, which often results in cost savings and bearings can be produced with high porosity, s that they can be soaked in oil and operated with littl or no added lubrication, depending on the service

Paint and Varnish Industry

Typical of the general uses of protective atmosphere in industry, aside from furnaces, are the application

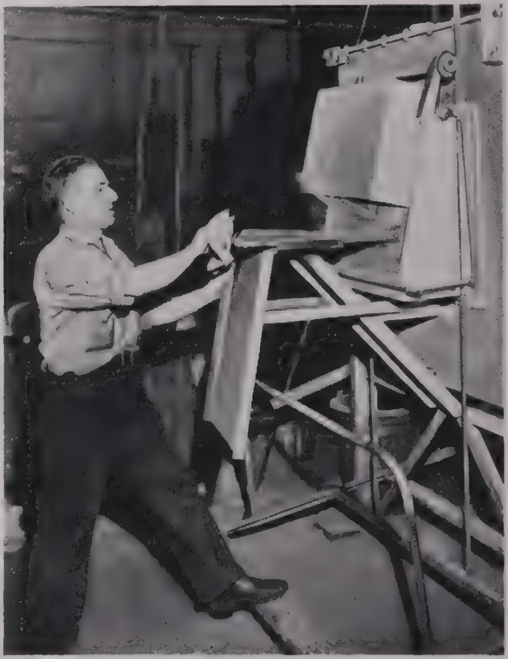

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Fig. 4. Trayload of steel subassembli being charged into a box-type coppe brazing furnace in which the atmospher prevent oxidation and thereby eliminat the need of a solvent flux

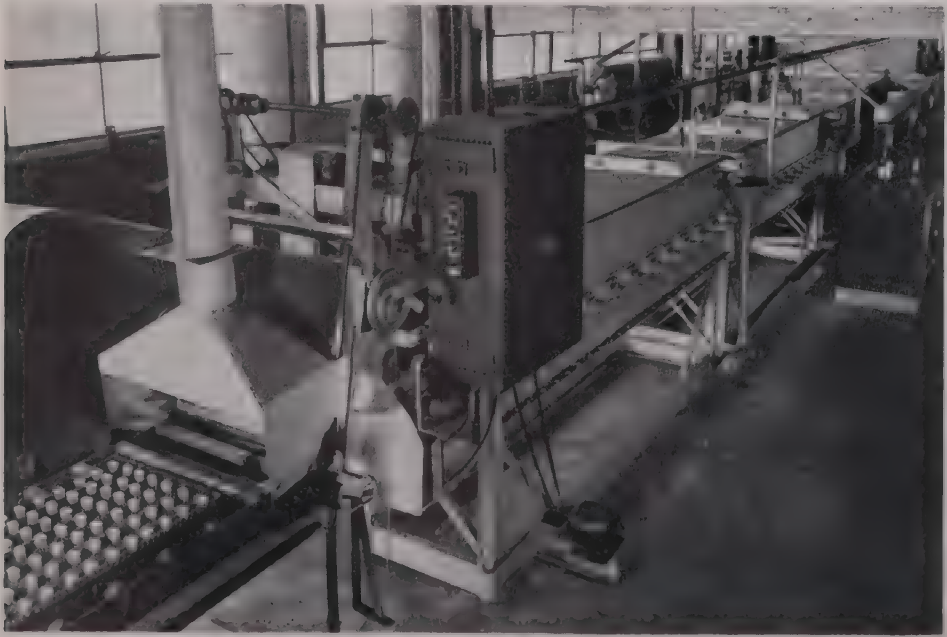

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Fig. 5. A roller-hearth sintering furnac from which a trayload of bearings is bein discharged

TABLE I

APPROXIMATE COMPOSITIONS AND COSTS OF PRODUCING TYPICAL PROTECTIVE ATMOSPHERES

tem	Protective Atmosphere	Type of Reaction	Air/ Natural-Gas Ratio	Composition—Percent						Dew Point (Deg F)	Cost Per M Cu Ft*
				Carbon Dioxide CO_2	Oxygen O_2	Carbon Monoxide CO	Hydrogen H_2	Methane CH_4	Nitrogen N_2		
A.	Hydrogen	Electrolytic									
	(1). Unpurified										
	(a). From cells**			0.0	0.2	0.0	99.8	0.0	0.0	Saturated	$1.55
	(b). From bottles (Purchased)			0.0	0.2	0.0	99.8	0.0	0.0	−30 to −10	6.00 to 12.00
	(2). Purified ¶										
	(a). From cells**			0.0	0.0	0.0	100.0	0.0	0.0	−60	1.57
	(b). From bottles (Purchased)			0.0	0.0	0.0	100.0	0.0	0.0	−60	6.01 to 12.01
B.	Nitrogen										
	(1). Unpurified	Liquefaction and rectification of air									
	(a). From air liquefaction plant**			0.0	0.2	0.0	0.0	0.0	99.8	Saturated	0.50
	(b). From bottles (Purchased)			0.0	0.2	0.0	0.0	0.0	99.8	−30 to −10	8.00 to 10.00
	(2). Purified ¶										
	(a). From air liquefaction plant**			0.0	0.0	0.0	1.0†	0.0	99.0†	−67	0.54
	(b). From bottles (Purchased)			0.0	0.0	0.0	1.0†	0.0	99.0†	−67	12.00 to 14.00
C.	Carbon Dioxide										
	(1). Unpurified										
	(a). From "dry ice" (Purchased)			99.8	0.0‡	0.0	0.0	0.0	0.2§	−30 to +27	4.65
	(b). From bottles (Purchased)			99.8	0.0‡	0.0	0.0	0.0	0.2§	−30 to +27	9.30
D.	Dissociated Ammonia	Endothermic									
	(1). Untreated			0.0	0.0	0.0	75.0	0.0	25.0	−60	1.05 or 3.95
	(2). Burned with air										
	(a). Partially burned		1/1	0.0	0.0	0.0	24.0	0.0	76.0	Saturated	0.57 or 2.10
	(b). Completely burned		1.75/1	0.0	0.0	0.0	1.0	0.0	99.0	Saturated	0.72 or 2.70
E.	Combusted fuel gas	Exothermic									
	(1). Unpurified										
	(a). Partially burned		6/1	5.0	0.0	10.0	15.0	1.5	68.5	Saturated	0.10
	(b). Completely burned		10.25/1	11.5	0.0	0.7	0.7	0.0	87.1	Saturated	0.08
	(2). Purified										
	(a). Partially burned										
	I. CO_2-free & Dry (Neutralene)		6/1	0.0	0.0	10.5	15.5	1.5	72.5	−40	0.14
	(b). Nearly completely burned										
	I. CO_2-free & dry (Neutralene)		9.5/1	0.0	0.0	2.0	2.0	0.0	96.0	−40	0.13
	(c). Completely burned										
	I. CO_2-free & dry (Neutralene)		10.25/1	0.0	0.0	0.7	0.7	0.0	98.6	−40	0.13
.	Reacted fuel gas	Endothermic									
	(1). With air over catalyst										
	(a). Completely reacted		2.5/1	0.0	0.0	19.0	38.0	1.5	41.5	−10	0.22

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* Costs include only materials consumed, such as power, gas, and water. They do not include factors for obsolescence, installation, maintenance, labor, c. The estimates have been based on the following unit costs:

Power	1 cent per kw-hr	Carbon dioxide	
Natural gas	50 cents per M cu ft	Dry ice	4 cents per lb
Water	5 cents per M gal	Liquid	8 cents per lb
Ammonia	4 or 17 cents per lb (tank car or cylinder lots, respectively)		

**Gas delivered in pipe lines.

†Nitrogen is often purified of oxygen by adding hydrogen which combines with oxygen to form water. In another method, nitrogen is passed over hot pper which removes oxygen, in which case H_2 is 0.0 percent and N_2 is 100.0 percent.

‡Tests on various brands gave 0.00 to 0.06 percent oxygen.

§Tests on various brands gave 0.00 to 0.24 percent nitrogen.

¶Metal retorts are necessary in furnaces to avoid contamination of highly purified gases.

Table II

APPLICATIONS AND PROTECTIVE ATMOSPHERES RECOMMENDED FOR THEM

Application	Material to be Processed	Requirements			Temperature Range, (Deg F.)	Protective Atmospheres* Recommended
		Metallurgical or Chemical	Metal Surface Bright‡	Metal Surface Clean§		
Annealing	Low-carbon steels		x		1200–1350	E1a, A1a, A1b, D2a
	Medium- or high-carbon steels**	No decarburization	x		1200–1450	E2a, F1a
	Medium- or high-carbon steels†	No decarburization	x	x	1200–1450	E2b
	Alloy steels— **	No decarburization	x	x	1300–1600	E2a, F1a
	medium- or high-carbon †	No decarburization	x	x	1300–1600	E2b
	High-speed steels**	No decarburization		x	1450–1650	E2a, F1a
	High-speed steels†	No decarburization		x	1450–1650	E2b
	Stainless steels		x		1800–2100	A2a, A2b, D1
	Stainless steels			x	1800–2100	E1a
	Copper		x		500–1200	E1b, B2a, B2b, C1a, C
	Copper-nickel alloys		x		800–1400	E1a, A1a, A1b, D2a
	Brasses and bronzes			x	800–1400	E1b, E2b
	Silicon iron (Electrical sheets)	Strain relief		x	1450–2000	A1a, B1a, E2c, D1
	Silicon iron (Electrical sheets)	Strain relief and reduced magnetic losses		x	1450–2000	A1a, E1a**, D1
Normalizing	Low-carbon steels		x	x	1600–1850	E1a, A1a, A1b, D2a
	Alloy steels—medium- or high-carbon**	No decarburization	x	x	1500–2000	E2a, F1a
	Alloy steels—medium- or high-carbon†	No decarburization	x	x	1500–2000	E2b
Hardening	High-carbon or carburized steels	No decarburization	x	x	1400–1750	E2a, F1a
	Alloy steels—medium or high-carbon	No decarburization	x	x	1400–1750	E2a, F1a
	High-speed tool steels	No decarburization	x	x	1800–2400	E2a, F1a
Brazing	Low-carbon steels	Copper braze	x		2050	E1a, A1a, A1b, D2a
	Medium- or high-carbon steels	Copper braze (No decarb.)	x		2050	E2a, F1a
	Alloy steels—medium- or high-carbon	Copper braze (No decarb.)	x		2050	E2a, F1a
	Stainless steels	Copper braze (Without flux)	x		2050	A2a, A2b, D1
	Stainless steels	Copper braze (With flux)		x	2050	E1a, A1a, A1b, D2a
	Cast iron	Silver braze (With flux)		x	1100–1600	E1a, A1a, A1b, D2a
	Medium- or high-carbon steels	Silver braze (With flux)		x	1100–1600	E2a, F1a
	Copper or brass	Silver braze (With flux)		x	1100–1600	E1b, E2c, B1a, B1b
Sintering	Low-carbon ferrous metals	Sintering	x	x	1800–2100	E1a, A1a, A1b, D2a
	Medium- or high-carbon ferrous metals	Sintering (No decarb.)	x	x	1800–2100	E2a, F1a
	Nonferrous metals: copper, copper-lead, copper-tin-graphite, etc.	Sintering	x	x	1300–1900	E1a, D2a
	Tungsten	Sintering	x	x	2150–2500	A2a, A2b, D1
	Molybdenum	Sintering	x	x	2150–2500	A2a, A2b
	Alnico magnets	Sintering	x	x	2150–2500	A2a, A2b, D1
	Stainless steels (with titanium or columbium)	Sintering	x	x	2150–2500	A2a, A2b
Gas carburizing	Low-carbon steels	Carburizing		x	1600–1750	Natural gas or propan E2a¶, F1a¶
Carbon restoration	Medium- or high-carbon steels, alloy steels—medium- or high-carbon	Carburizing		x	1500–1650	E2a, F1a
Nitriding	Alloy steels (Nitraloys)	Nitriding		x	1000	Ammonia (NH_3)
Oxide prevention in storage, cooking, etc. Fire prevention and extinguishing Explosion prevention	Paints and varnishes	No oxidation			Ambient	E1b, B1a, B1b, C1a, C
	Synthetic resins and synthetic varnishes	No oxidation			300–500	E1b, B1a, B1b, C1a, C
	Rubber bags for curing tires	No oxidation			200	E1b, C1a, C1b
	Canned fruit juices	No oxidation			Ambient	E1b
	Dusts	No oxidation			Ambient	E1b
Sodium hydride descaling	Oxidized metals such as stainless and alloy steels	Reduction		x	700	A1a, A1b, D1
Atomic hydrogen welding	Ferrous metals	Reduction		x	10,800 (arc)	A1a, A1b, D1
Hydrogenation	Oils, fats, lards, etc.	Hydrogenation			250–500	A1a, A1b, D1

*See Table I for approximate compositions and costs of protective atmospheres.

**For treating metals on short cycles.

†For treating metals on long cycles.

‡A "bright" surface from the furnace is approximately as clean and bright as that of the work charged into the furnace.

§A "clean" surface is free from heavy scale, but discolored by oxide or flux deposits requiring light cleaning to restore brightness.

¶Carrier gas enriched with natural gas or propane.

n the paint and varnish industry, where the atmospheres serve a variety of purposes. Paints, varnishes, nd oils have a tendency to oxidize and form skins in storage tanks and pipelines in contact with air, particuarly after supplies are depleted. This involves costly nd objectionable cleaning operations, which have been eliminated in various plants by injecting inert protective tmospheres in the tanks and lines, starting from the ime the materials are drawn from them.

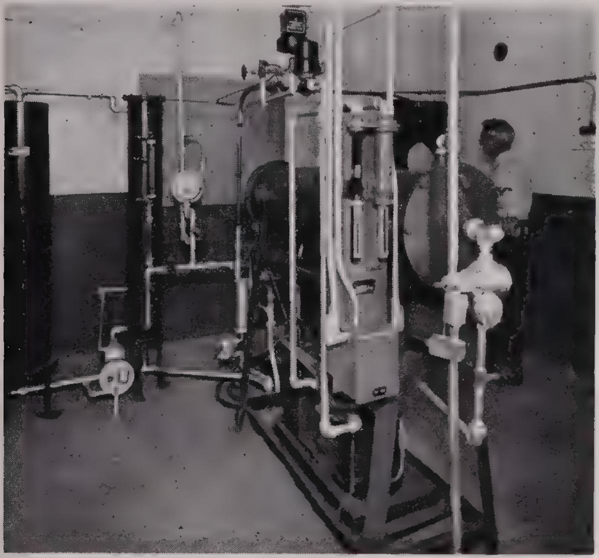

Fig. 6. An atmosphere-gas converter with auxiliary equipment supplies protective atmospheres for bubbling batches of resins and bodying oils during cooking. Savings result from replacing carbon dioxide with this less expensive gas

The same protective atmospheres improve quality of ynthetic resins during cooking, and also reduce costs. or example, nitrogen and carbon dioxide have commonly been used, being bubbled through the kettles of esin to help remove water vapor and to provide agitaion. But combusted gas, because of its complete freeom from oxygen, gives the lightest possible color—a istinct advantage—at lower cost.

Still another use for the inert combusted-gas atmosheres is in blanketing to prevent or extinguish fires. arbon dioxide has been employed for this purpose, ut inert combusted gas has afforded greater safety hrough its wider use, as a result of its low cost. An tmosphere-gas converter with auxiliary equipment for he applications described is illustrated in FIG. 6.

nalyses, Costs, and Applications

Typical gases used for protective atmospheres are dicated in Table I, including their analyses and aproximate costs. Each of these atmospheres and the ethod of producing it will be fully described in a cceeding part of this series.

Listed in Table II are applications for protective mospheres, the requirements to be met, and the commended atmospheres for each application. Most these applications also will be described in detail in ater part. *(To be continued)*

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC., REQUIRED BY THE ACT OF CONGRESS OF AUGUST 24, 1912, AS AMENDED BY THE ACTS OF MARCH 3, 1933, AND JULY 2, 1946

Of GENERAL ELECTRIC REVIEW published monthly at Schenectady, New York, for October 1, 1948.

State of New York
County of Schenectady } ss.

Before me, a Notary Public in and for the State and county aforesaid, personally appeared E. C. Sanders, who, having been duly sworn according to law, deposes and says that he is the Executive Editor of the GENERAL ELECTRIC REVIEW and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily, weekly, semiweekly or triweekly newspaper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Acts of March 3, 1933, and July 2, 1946 (section 537, Postal Laws and Regulations), printed on the reverse of this form, to wit:

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(Signed) E. C. Sanders
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SINGLE-TURN A-C RING TESTER FOR MAGNETIC LAMINATIONS

Construction, operation, and applications of a simple tester approaching in speed of performance a magnetic comparator and useful in many quality-control applications

James H. Wright

By DR. J. H. WRIGHT
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MAGNETIC testing plays an important part in industry today, both for development of improved materials and for quality control in manufacturing. Many different types of testing equipment are available and each one has its particular usefulness. Some are designed to obtain accurate, fundamental data, even though considerable time and expense may be involved in preparing samples, operating the test, and calculating the results.(1) The ballistic ring test, various permeameters, and the Epstein test are in this category.

Other types are designed primarily for speed in determining whether a specimen or a magnet is acceptable for a particular application, or whether its properties fall in a certain range.(2) In this class are various tractive and flux tests, magnetometers, and magnetic comparators.

Still other devices, like the cathode-ray hysteresiscope, for example, are borderline cases.(3)(4)(5) With certain types of samples and conditions of use, the results approach a fundamental form, but under other conditions only a comparison of specimens is attempted. Such a device is the one which is described in this article and which may be called a single-turn a-c ring tester. It is suitable for use with high-permeability materials in the form of rings or other closed-circuit shapes, and results on concentric ring samples may be translated into curves of B vs. H, or a-c permeability.

With this device, laminations may be tested singly or in stacks as required. No preparation time is necessary, as for example putting on windings for the ballistic ring test. The specimen is mounted for test in a few seconds and results are obtained in the time required to take the desired number of readings. This is somewhat longer than the time with a magnetic comparator, but the single-turn a-c ring tester has the advantage of employing a magnetic circuit completely within the specimen, which gives higher sensitivity and results of more fundamental meaning.

CONSTRUCTION AND OPERATION

Basically the single-turn a-c ring tester consists of one turn of wire to carry a magnetizing current and one turn of wire to measure a-c flux. Both of these pass through the opening in the ring to be tested. All othe components of the device assist in the functioning one or the other of these circuits. Fig. 1 shows diagram of connections. Power from a 120-volt 60-cycl supply is controlled by means of a variable autotrans former to produce a current I', in a circuit which i cludes the resistance R and the low-current winding of current transformer. The current I' ranges from zero t about 1.5 amp.

To the high-current winding of the current trans former is connected only an ammeter and a section straight conductor conveniently arranged with a sup port for the specimen and a spring clip for quick con nection. With a transformer rated 100 to 5 amp

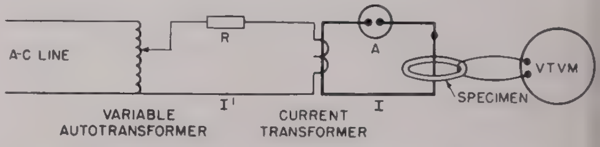

Fig. 1. Diagram of connections for single-turn a-c ring tester

the current I in this circuit reaches about 30 amp The other turn linking the specimen is connected to high-sensitivity vacuum-tube voltmeter of the typ which responds to average rectified values. Fig.

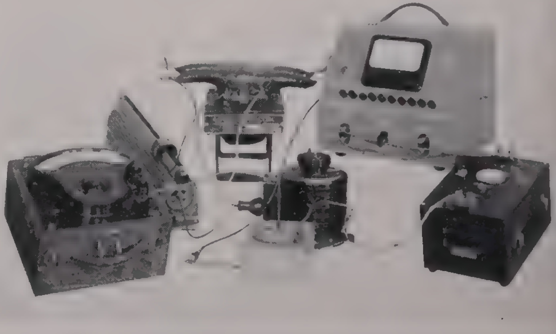

Fig. 2. General view of the tester set up for use

shows a general view of the complete arrangemen All parts of the circuit except the mounting fixtur consist of standard measurement equipment.

The lamination or core assembly to be tested is firs placed on the fixture and the clips connected. N

This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

(1) Numbered references are listed at the end of the article.

special care has been found necessary in positioning the specimen with respect to the magnetizing conductor, although it is well to make the two approximately concentric. The magnetizing current I is varied at will and corresponding values of induced voltage read on the voltmeter. With a sinusoidal voltage supply the magnetizing current is closely sinusoidal because the resistance R represents nearly all of the circuit impedance.

From the indicated rms current the peak magnetomotive force can be calculated, and if the specimen is a ring of uniform radial width the peak magnetizing force H_m can be obtained. The equation becomes

$$H_m = 0.223\ I/d$$

where I is rms amperes, and d is the mean diameter of the ring in inches. With a current of 30 amp and a

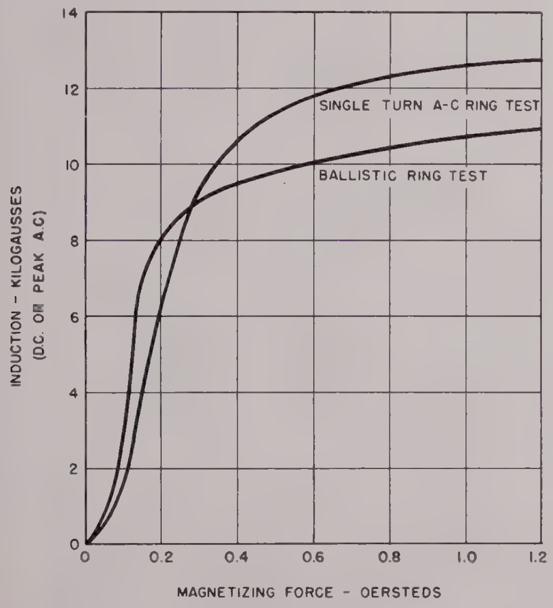

Fig. 3. *B-H* curves for Nicaloi rings by ballistic and a-c test

ing of 2-in. diameter this corresponds to a magnetizing orce of 3.35 oersteds, which is ample for most tests on igh-permeability material. If the diameter is smaller, a lower current will produce the same magnetizing orce.

In a similar way, readings of induced voltage may be nterpreted as peak flux. With a 60-cycle supply and vith a voltmeter reading 1.11 times average rectified oltage, this is given by

$$\Phi_m = 375{,}000\ E$$

vhere Φ_m is the peak flux in maxwells and E is the voltmeter reading. The result is independent of wave shape o long as the wave of induced voltage does not cross he axis more than twice per cycle.(6) A vacuum-tube oltmeter found useful in this application reads down o ten microvolts with the aid of a pre-amplifier. Thus a flux of 3.75 maxwells can be measured.

If the cross-sectional area of the specimen is uniform, he flux can be expressed in terms of induction B. Calculation shows than an induction of 2000 gausses can be measured in a specimen having a cross-section of only 0.00029 square inch. Smaller laminations are seldom encountered, but, at some extra trouble in testing, this range may be extended by passing the flux winding more than once around the specimen.

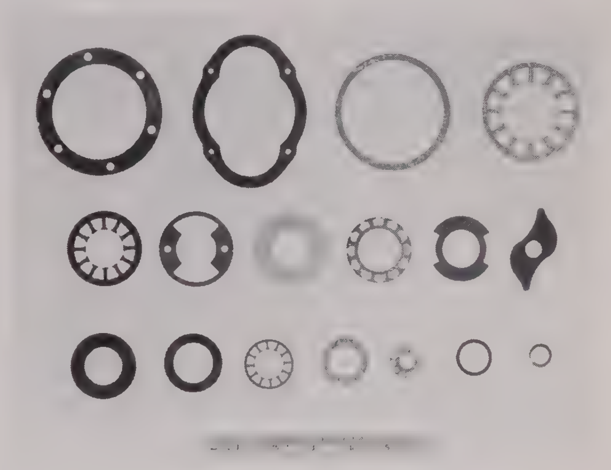

Fig. 4. Typical lamination parts on which the tester can be used

For laminations of high-permeability material, no precautions need be taken to place the flux winding close to the specimen. The space flux is negligible compared to the flux in the magnetic material.

APPLICATIONS

Small laminations can be tested in the manner described as a check on the quality or treatment of the material. Any number of values of magnetizing current may be used but a very few will often suffice for an adequate quality-control test, particularly after experience has been gained with the material being tested. The method uses a minimum of material to make the test, one small ring being sufficient. The time to mount the sample in place is a matter of five or six seconds, compared to perhaps 15 or 20 minutes to put on windings for the ballistic ring test.

The results are not exactly the same as by the ballistic test, as a-c and d-c measurements of magnetic properties always show differences. Fig. 3 shows curves on Nicaloi ring samples by the two methods. No attempt has been made to account in detail for the difference or to determine whether it agrees with that normally found. In any given case, acceptance requirements may be expressed in terms of the a-c test; and this is often to be preferred as it corresponds to the actual use of the material. For highest accuracy in measuring flux a comparison method of determining voltage value can be used rather than the actual voltmeter readings.

If absolute values of B and H are not needed, or cannot be obtained because of irregular specimen shape, the tester can be used as a comparator. It can test any lamination which provides a closed magnetic circuit. Fig. 4 shows a number of production parts on which

(Concluded on next page)

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tests have been made. They are components from measuring devices. In cases where the cross-section along the flux path is not uniform, the flux winding can still be used to measure induction B at a chosen point, even though magnetizing force H at the same point cannot be determined. Results of such a test are given in Fig. 5, where induction in gausses is plotted against magnetizing force in amperes. Specimens of identical shape but different material were used. The relative magnetization curves of silicon steel, Nicaloi, and Mumetal are easily recognized.

The tester has been found very useful in segregating mixed stock and detecting faulty heat treatment. While other magnetic comparators can be used for this service, this one has greater sensitivity by virtue of employing a magnetic circuit completely within the material tested. This sensitivity is particularly useful in determining the effect of the pressure and strain to which laminations may be subjected in an assembly.

In some applications of magnetic cores, a selection of laminations for uniformity or a matching of assemblies must be made. For this service direct measurements can be made of the individual parts, or two can be compared differentially by placing both on the fixture and passing secondary turns in series around the two in opposite directions. Units may be paired to keep the indicated difference below a selected level, although the voltmeter reading in this case is not necessarily a measure of the maximum difference in flux.

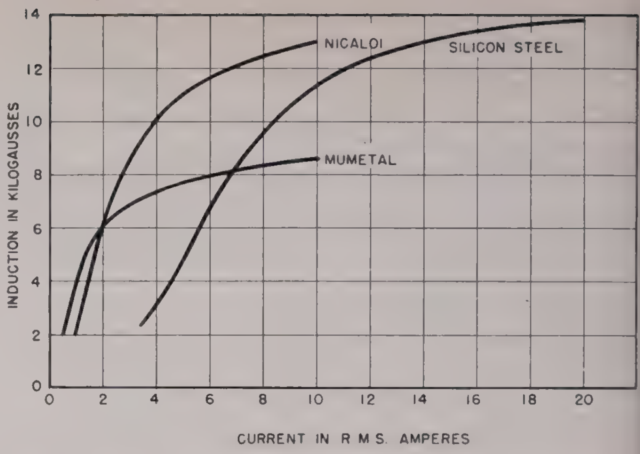

Fig. 5. Induction vs. magnetizing current curves for laminations of identical shape but different materials

CONCLUSIONS

The tester described, while it adds to the already numerous equipments available for magnetic testing, has been found a useful tool for the magnetic laboratory. With respect to speed and convenience, it approaches the performance of a magnetic comparator. At the same time it is close enough to an absolute measuring device to be an acceptable substitute for the ballistic ring test in many quality-control applications.

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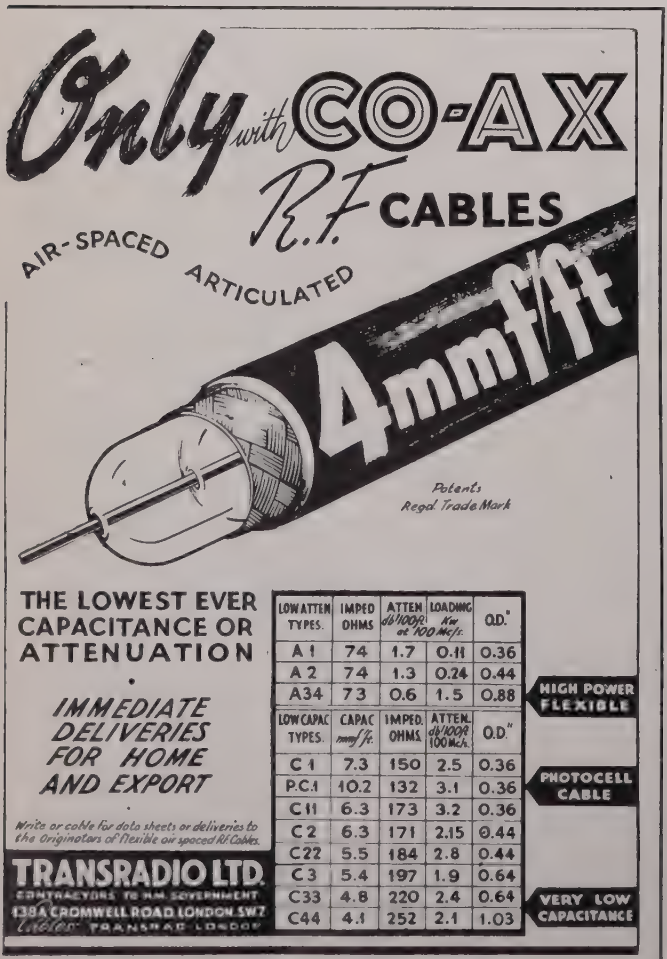
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C 11	6.3	173	3.2	0.36
C 2	6.3	171	2.15	0.44
C 22	5.5	184	2.8	0.44
C 3	5.4	197	1.9	0.64
C33	4.8	220	2.4	0.64
C44	4.1	252	2.1	1.03

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THE RESEARCH CHALLENGE IN AIRCRAFT PROPULSION

E E Stoeckly

The challenge presented by powerplant factors that immediately come to mind and by other less obvious factors chargeable to the powerplant. Their influence on the over-all performance of aircraft powered by different types of powerplants is analyzed and an outline given of the design problems that lie ahead

By E. E. STOECKLY

Aircraft Gas Turbine Engineering Division
General Electric Company

FROM the very beginning of man's success in conquering the air, the propulsive powerplant of the aircraft has presented the principal limitation to the aircraft's speed, range, and load-carrying capacity. Thus, if we are to achieve and maintain a position of world leadership in the air, it is imperative that we assign to the propulsion problem a key position in our research and development programs.

The development of aircraft propulsion systems can be divided into three periods: that of the reciprocating powerplant; that of the air-breathing reaction powerplant; and that of the non-air-breathing, or rocket, propulsion powerplant. The first period, that of the reciprocating powerplant, embraces the entire interval of time from the beginning of aeronautical development—when a converted automobile engine was used as the prime mover—up to the present time.

The second period is that of the air-breathing reaction jet-propulsion powerplant, beginning some ten years ago and developing very rapidly during the last five. This period should bring the solution to the major propulsion problems falling within the scope of subsonic flight and, in a more limited degree, to those in the transonic and lower supersonic ranges. The limits of flight performance with this type of powerplant may possibly reach speed values well above sonic at flight altitudes of possibly 60,000 ft and with a range possibly up to 10,000 miles.

The period of the non-air-breathing, or rocket, propulsion powerplant, useful principally for propulsion at supersonic flight velocities at high altitudes, has just begun. Since this period is so near its beginning in research and engineering development and its potential possibilities so great, its outcome cannot be clearly foretold. For this reason it is hazardous to forecast the probable limits of performance that might be expected; suffice it to say that speeds of several times that of sound, extreme altitudes, and appropriate radius of action will be achieved.

To aircraft powered by reciprocating engines, such as this Boeing Stratocruiser, turbo superchargers add speed, altitude, and range

RECIPROCATING POWERPLANT

In view of the past development of the reciprocating powerplant and the present existing state of engineering knowledge, it does not appear that any grand new fundamental improvements are to be expected in this type of powerplant in the near future. During the past thirty years, power demands for improved flight performance have risen from several hundred horsepower to several thousand horsepower. These demands have been met partly by improvements in the combustion process and by the use of higher-grade fuels which make it possible to increase more and more the output of a given cylinder; but it also was obtained in part by an increase in the number of cylinders. The growing knowledge of the thermodynamics of the engine, and the internal actions in it, has resulted in decreasing specific fuel consumption and decreasing specific weight for given output horsepower.

Both the takeoff and altitude performance have been materially increased by the use of geared and turbosuperchargers, intercoolers, aftercoolers, water injection, exhaust jets, etc. Engine cooling, particularly of the aircooled engine at altitude, has been a limiting factor.

While not suited for high-speed military aircraft, the reciprocating engine, particularly when properly compounded with turbo elements, will continue to play a most important part in the transport, cargo, and moderate-speed long-range bomber fields. Its principal long-range future may very well turn out to be a high-pressure topping unit for turbo elements.

This article was presented at the annual meeting of the American Society for Engineering Education, June 15, 1948, Austin (Tex.).

This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

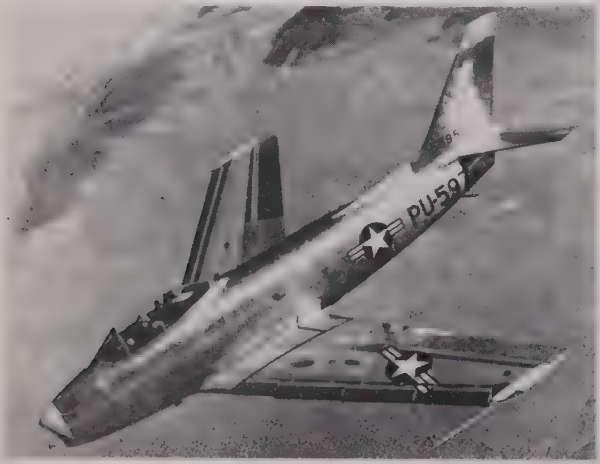
GAS-TURBINE POWERPLANTS

As improvements in the aerodynamic characteristics of the airplane, coupled with increased engine output, have combined to steadily increase the speed, range, and altitude characteristics of aircraft, the proper evaluation of the propulsion system becomes more and more important.

The higher military aircraft speeds have resulted in lower propeller efficiencies and increased air intake and powerplant-nacelle drags to the point where the net thrust that a reciprocating-engine powerplant delivers back to the aircraft frame becomes increasingly a smaller part of the gross engine output.

It was the recognition of this fact some ten years ago that prompted the development of air-breathing reaction jet-propulsion powerplants. As used here the term refers to all jet-propulsion powerplants in which the oxygen required to burn the fuel is taken from the surrounding atmosphere. Strictly interpreted, this definition would also include the reciprocating-engine powerplant in which the jet is produced by the propeller. Such a plant is not included here because it has already been discussed.

As aircraft flight speeds approach sonic values, additional increases in speed will be possible only if the individual factors causing losses are separately considered and everything possible is done to minimize their effects. Thus, if the maximum in aircraft performance is to be obtained, it is imperative that the propulsive-powerplant designer concern himself not merely with the net output of the engine, but also with the net effective thrust transmitted to the main aircraft structure. This effective thrust is obtained by subtracting from the gross engine output its own ram drag, cooling-air drag, powerplant-nacelle drag, and the interference drag caused by the addition of the engine nacelle to the wing. If the engine is not placed in a separate nacelle, its proportional increase in the drag of the main fuselage or other housing must be charged to the engine. As engine weight and shape change, so also must the weight and possibly the shape of the wing structure and the landing gear necessary to support the additional weight. Higher specific fuel consumptions require not only increase in fuel but also added fuel tanks, space, and added plane structure to carry them. This added weight requires added engine power and fuel to carry it for a given range and payload.



A single turbo-jet engine powers the present holder of the world's speed record, 671 mi per hr: the North American F-86

Eight jet engines are installed in the Northrup YB-49 "Flying Wing," which has a wing span of 172 ft, length 53 ft, weight 200,000 lb, and exceptional speed for its size

That those factors become more and more important as aircraft speeds increase was clearly demonstrated recently in a very careful analysis of a new high-speed plane. Two different engines were considered. The one of lighter weight, higher thrust, larger frontal area, and somewhat higher specific fuel consumption appeared at first to be the better choice. When all factors were properly evaluated, however, the better altitude, better specific fuel consumption, and greater inlet efficiency of the heavier engine more than offset the other's apparent advantage of lower weight and higher thrust rating and resulted in a plane with higher top speed and greater range. For other applications under different circumstances the results could have been entirely different. Thus, we see the necessity for ever-increasing co-ordination that must exist between the powerplant designer and the aircraft designer in order that the powerplant and aircraft can be tailored for each other's needs. As flight speeds increase, the characteristics of engines themselves change. Thus, under different conditions different types of powerplants show up more favorably.

TURBINE-PROPELLER POWERPLANTS

For the lower aircraft speeds, and competing with the reciprocating engine, is the turbo-propeller engine which generally consists of a simple, open-cycle gas turbine driving a conventional propeller. At average flight speeds, optimum performance is generally attained when about one quarter of the output is taken in the form of exhaust-jet reaction. This division of power helps to decrease the weight and size of the turbine and exhaust system. When built with comparatively high component efficiencies, at reasonable pressure ratios and for turbine-inlet temperatures that are feasible today, its specific fuel consumption approaches or equals that of the simple reciprocating engine, particularly at full load where its specific fuel consumption is at its lowest value. Compared with the reciprocating engine it is usually lighter in weight, presents less frontal area, occupies less space, and requires little or no cooling air.

Although the smaller frontal area and lack of cooling-air requirements of the turbo-propeller powerplant makes possible smaller engine nacelles and lowers their drag, which increases the effective powerplant output, there remains the same loss of propeller efficiency as for the reciprocating engine, as flight speeds ncrease. While present-day reciprocating engines appear to be approaching a practical power limit, turbo-propeller engines are entirely feasible in considerably arger capacities. This fact may be a very important one in the future of the simple open-cycle turbo-propeller engine. The most important factor in the development of this powerplant is to still further mprove its fuel economy.

Six jet engines and eighteen Jato rocket assist units are combined in the takeoff of this Boeing XB-47, capable of a speed of 650 mi per hr

Some thought and study has been given to cycle modification that can be used to increase the over-all performance. Compressor intercoolers, turbine inner-stage reheating, and exhaust heat exchangers have been onsidered, but until research and development can mprove the performance of these new elements above what they are now, they are of doubtful value for aircraft installations. In general, the price paid in ncreased cycle pressure drop, weight, frontal area, ooling-air drag, and added complications does not ustify the probable gains.

Another promising hope is the use of basically higher ffective temperature cycles. The present state of our materials development will not allow us to operate teady state at appreciably higher temperatures than we now do. Many ingenious cooling systems have been and are being tried, here and abroad, for cooling both the diaphragm and the turbine blading.

The Otto engine operates on a high temperature cycle without any of the parts actually reaching the peak temperature. This is accomplished by compressing relatively cool air and expanding high-temperature gases in the same cylinder, thus exposing the metal alternately to low and high temperatures. Because of the short exposure time the metal assumes an intermediate temperature. This suggests that we replace the constant-pressure combustion chamber by a reciprocating engine. The power output of the reciprocating engine could then be geared to either the compressor or the propeller. The capacity of a given engine should be high because of the high pressure level.

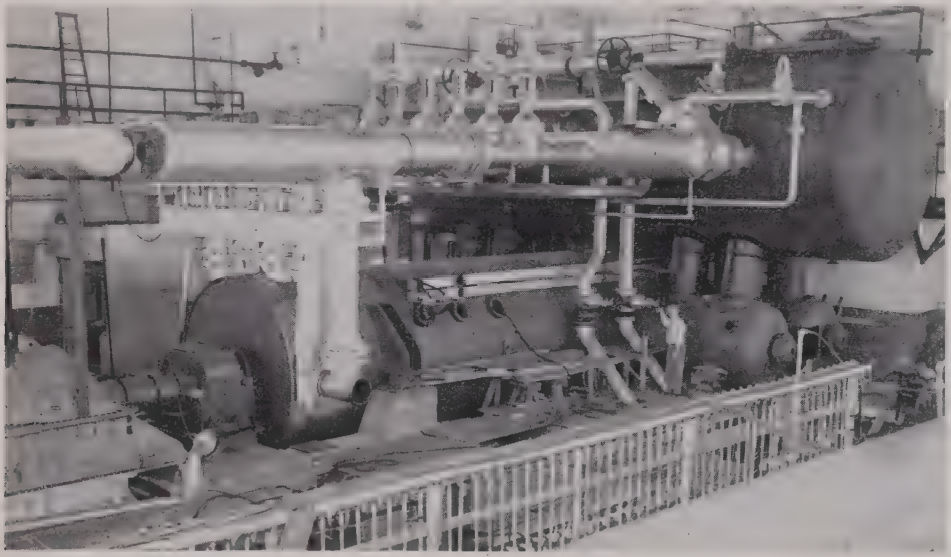
Other modifications might be the use of a free-piston, or crankless swashplate type, engine in which the net output results in delivering the gases to the turbine at a higher pressure than received from the compressor. A possible way of accomplishing the purpose of the free-piston engine, and yet avoiding many of its complications, is the use of the recently announced Brown-Boveri "comprex" in which compression of the air and expansion of the hot gases is accomplished by the use of pressure waves taking place in cells of a rotating drum. Because of its nature, this may have to be a device useful principally as a base-load powerplant. Another possibility is that of superimposing the Karavodine, or pulse-jet, cycle on top of the Brayton cycle. This would result in replacing the present constant-pressure combustion system by one more nearly approaching constant-volume combustion. The problems of valving, combustion, and turbine performance under the variable conditions remain to be solved.

The approach to the problem of achieving the benefits from such improved cycles, without paying unduly in terms of weight, space, frontal area, reliability, and mechanical complications, is continuously being pursued by development and research engineering.

TURBO-JET POWERPLANT

The most popular currently used reaction powerplant is the turbo-jet engine. This engine generally employs the gas-turbine open cycle, delivering its power output in the form of jet reaction of the exhaust gases rather than as mechanical power. In such a cycle, the absolute jet velocities are such that the cycle compares favorably in performance at flight speeds of 400 miles per hour and higher with turbo-propeller and reciprocating-engine performances. At such speeds, where the flight velocity becomes a larger proportion of the jet velocity, the over-all performance increases and the turbo-jet rapidly overtakes and exceeds the performance of the other powerplants. The major portion of contemporary effort has been directed to the improvement of this basic cycle.

Improvements in the efficiency of component elements will always help to improve both the specific fuel consumption and the capacity for a given frame size. As development progresses and efficiencies increase, gains will become increasingly more difficult to attain without paying unduly in weight and space. For given component efficiencies and turbine inlet temperatures, gains (particularly in design specific fuel consumption) may be made by increasing the pressure ratio up to a certain value, beyond which losses appear. Present-day permissible turbine inlet temperatures and attainable component efficiencies still are below optimum pressure-ratio values.



This compressor test stand is probably the most advanced equipment of its type in existence. It is designed to evaluate turbo-jet compressor performance under conditions simulating those encountered on practically any flight. Note comparative size of operator

The chief hazard in higher pressure ratios lies in the fact that it is increasingly difficult to control the matching of compressor and turbine elements as pressure ratio is increased. Peak efficiencies, particularly of the high-pressure-ratio compressors, usually lie close to the stall limits.

To meet off-design operating conditions, the designer is forced to design for operation below peak efficiencies or by other means he must artificially avoid operation in the stall region. The most difficult conditions are starting, part-speed operation, and acceleration.

Present knowledge of the design factors in axial-flow compressors that control the location of the stall line in relation to the peak-efficiency lines is still so limited that its location and shape is a matter of determination by experiment rather than by deliberate design. This will continue to be true until research and analysis develops a more complete and exact design theory for the axial-flow compressor.

For given plane speeds, compressor pressure ratios, and component efficiency characteristics, there is a definite turbine inlet temperature for minimum specific fuel consumption. For present-day speeds, pressure ratios, and component efficiencies, minimum specific fuel consumptions are attained at less than maximum permissible turbine-operating temperatures. Thrust capacities, however, always increase with turbine inlet temperature so the designer is generally forced to compromise. As the cycle pressure ratio increases, the optimum turbine inlet temperatures for minimum specific fuel consumption also increases. Thrust capacities, however, are affected only in a minor way by pressure ratio.

To improve the performance of the turbo-jet engine at low airplane speeds, various forms of thrust augmentation have been used. These include rotary augmenters, ducted fans, and divided flow cycles. All have as their purpose the moving of a greater mass of air at a velocity more nearly approaching that of flight. In a sense, they become a cross between the open propeller of the turbo-propeller engine and the pure jet of the turbo-jet engine. The addition of such devices has, in general, been effective in reducing the specific fuel consumption at low air speeds but has become a distinct loss at higher plane speeds. In general, they increase the weight and frontal area for a given capacity and, because of their higher air flow per pound of thrust, they become more sensitive to ram efficiency. The aircraft speed at which such augmentation schemes change from a gain to a loss can be partially controlled by the ratio of air augmentation, pressure ratio of the cycle, and operating temperatures.

Our imagination is still intrigued by the possibility of adapting to the turbo-jet engine many of the schemes suggested for the turbo-propeller engine. Theoretically, gains can be shown by replacing the constant-pressure combustion system by reciprocating engines, pressure-raising free-piston gas generators, and by the use of pulse-jet and "comprex" cycles.

RAM JETS AND PULSE JETS

Air-breathing reaction powerplants of a third form are those which have no rotating parts and which depend upon ram or wave-motion pressure for the compression part of the cycle. The principal examples of these types are the athodyd or ram-jet and the pulse-jet cycle. Because of the peculiar characteristics of specific fuel consumption and thrust with speed of the ram jet, its principal field of application is at high speeds and high altitudes on aircraft or devices which must be launched or started by other propulsive means.

OMPARISON OF THE SYSTEMS

Having touched briefly on the various forms of ropulsion systems, we should take stock at this time f what can be accomplished with them, what it is hat we would like to accomplish, and what is the esearch and engineering development challenge that nust be met if we are to achieve our desired goal.

Obviously, because of military restrictions, the latest levelopments and accomplishments cannot be re- ealed. However, for the purpose of this article an nalysis prepared by Dr. Neugebauer of the Aero- autical Research Establishment at Munich for the erman Air Ministry will be helpful. His report, first ssued on March 14, 1945, is essentially the best German valuation of the engineering possibilities at the time f V-E day and provides an evaluation of the possibili- ies that continued research and development might ave produced for the Germans. As the Germans were levelopmentwise somewhat ahead of us in some of hese new propulsion systems, the picture presented is probably not too far in error today. FIGS. 1 to 5 inclusively sum up briefly the speed and range characteristics at constant flight altitude of propulsion systems possible today when applied to appropriate aircraft.

The comparison between the different propulsion systems is made on the basis of ton-miles of armament or cargo that can be transported per ton of fuel consumed, at various plane speeds, ranges, and altitudes. While it is realized that to attain maximum range with a given aircraft, operation will be at various altitudes, actual obtainable ranges will then tend to be somewhat more than is shown in the charts. This gain, however, will be partially offset by the loss of range resulting from the time taken to climb to altitude and to descend.

The cusps in the ton-miles per ton fuel curves, particularly noticeable in the chart for 40,000 ft altitude, are explained as follows: For the portion of the curves below the cusps, the range is determined by takeoff conditions; for the portion above the cusps, by wing-loading and landing. In general, these charts show that

Figs. 1 to 5. Charts comparing different propulsion systems on basis of ton-miles per ton of fuel consumed, at various plane speeds, ranges, and altitudes

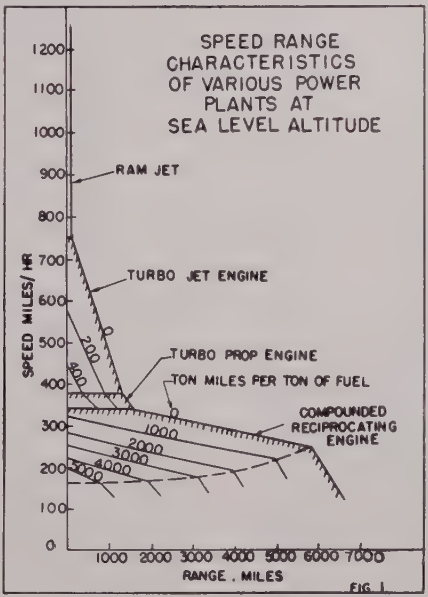


FIG. 1

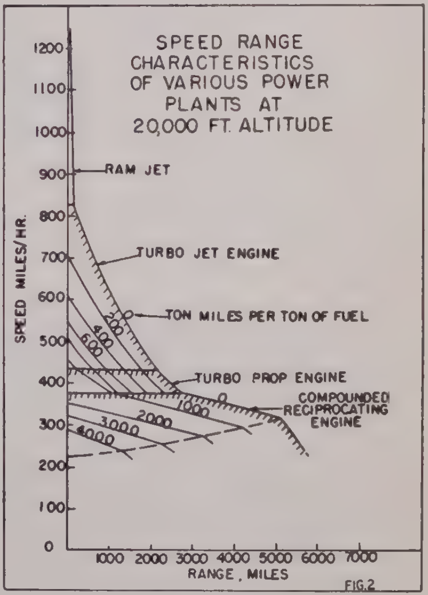


FIG. 2

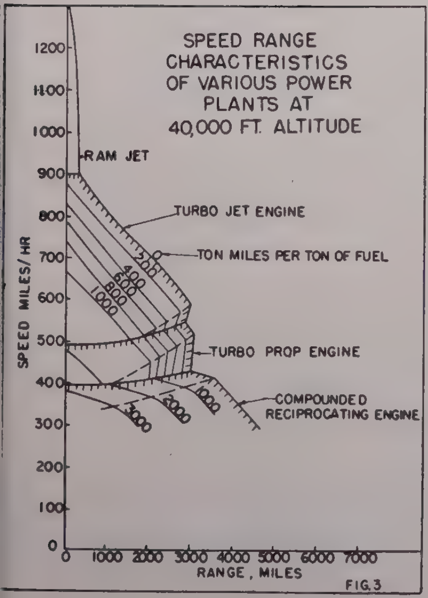


FIG. 3

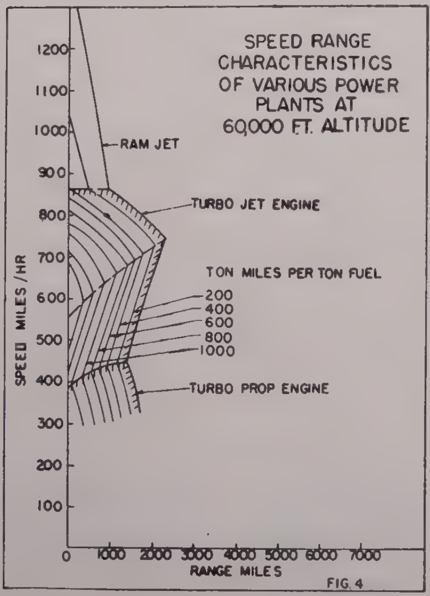


FIG. 4

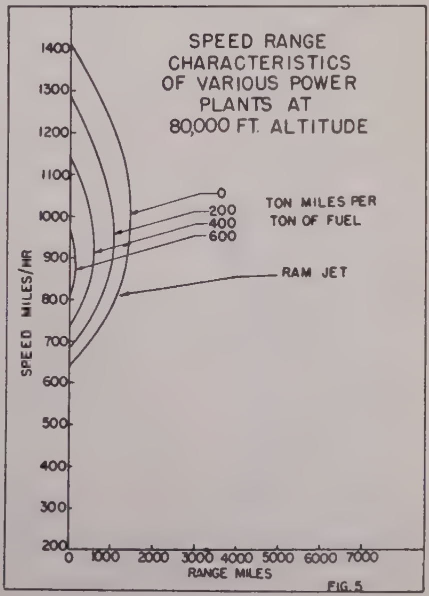


FIG. 5

very long ranges can be attained at this time only by compounded reciprocating engines and low flight speeds. The reciprocating engine loses its advantage to the turbo-propeller engine when flight speeds reach 350 miles per hour and higher. At speeds above 400 miles per hour at sea level and at 500 miles per hour at 40,000 ft altitude, the turbo-jet predominates the field. The ram jet is of little importance except at speeds above sonic and at high altitudes.

Outstanding in these charts is the small significance which the turbo-propeller engine appears to have at all altitudes. As research and development progress and the specific fuel consumption of the turbo-propeller engine is improved, the area of its region on the chart may increase. However, it will be recognized that many developments in materials and in component efficiencies which would improve the turbo-propeller cycle may also be applicable to the improvement of the turbo-jet engine. It may well be, therefore, that the future may bring about a displacement of this area rather than any large change in its relative size.

At the end of the last war it was the belief of those in Germany who directed the research and engineering development of propulsion systems that the reaction jet propulsion powerplant essentially in the form of the turbo-jet engines with necessary modifications could eventually be developed for speeds somewhat above sonic at altitudes up to 65,000 ft, and for ranges up to 9500 miles. These may seem ambitious goals to shoot for and it is certainly true that we are still a long way from attaining them. It is, however, the author's firm belief that we will meet the research and engineering development demands before us and that these goals will not only be met but exceeded.

SOME OF THE PROBLEMS FACING THE DESIGNER

There is a tremendous premium on size, weight, performance, and reliability in aircraft gas turbines. It was adequate for the first crude engine to design primarily for high component efficiencies. In successive designs, more and more air flow must be crowded through the same outer envelope in efforts to obtain more output from the same size package. This urge for increased output per inch of diameter and per pound of weight and with improved component efficiencies at higher pressure ratios per stage requires constant and imaginative research and design thinking and application.

The problems faced in these efforts demand the development of more advanced theoretical and research techniques. Analytical means for treating truly three-dimensional flows, both subsonic and supersonic, within arbitrary boundaries are particularly needed. Little is known about the analysis of losses in wakes due to boundary-layer growth and shed vorticity.

For the axial-flow compressor there does not exist at the present time a completely adequate theory for accurately determining the flow characteristics around each blade and its resultant forces. The aerodynamic problem involves flow through lattices and it must take into account the three-dimensional nature of the flow and the effect of viscosity and of compressibility. At present, we have practically little knowledge that is basic concerning the relative merits of various blade profiles now used in axial-flow compressors. Basic design data have not yet been developed upon which to design a superior profile shape for a grid of airfoils. We need an airfoil for grids which parallels the role of the laminair-flow airfoil used for airplane wings. It is pertinent to point out that the development of the laminar-flow airfoil did not come about by hit-and-miss methods, but rather by the systematic analytical treatment of new theories of turbulence and boundary layers, and this was assisted by the development of the low-turbulent wind tunnel and by the creation of techniques for designing profiles to suit arbitrary pressure distributions.

Although the combustion system is a very important part of the present-day gas turbines, our knowledge of the kinetics of combustion is so limited that today's combustion chambers are developed almost completely on an empirical and cut-and-try basis.

A much better fundamental knowledge of the processes of combustion and the conditions surrounding it is imperative if we are to overcome the difficulties of increasing heat releases up to the twenty million and even to forty million Btu's per cubic foot per hour level necessary in engines of the future. The difficulties are not just those of obtaining the heat release in a given volume but also of obtaining highly efficient stable operation over a wide range of operating conditions, damping or elimination of high-frequencies pulsations, obtaining proper gas-temperature distributions, and cooling of chamber parts, and other problems.

The one component whose development, more than any other, delayed the attainment of the gas turbine on a practical basis was the turbine itself. Its design encompasses the sciences of aerodynamics, metallurgy, and elasticity. As the turbine-design art continues to grow, the complexity of the new and difficult problems that arise emphasizes the need for more effort in these fields.

New and more rational flow theories have been contributed by the aerodynamist. Their application to turbine design has yielded a slight improvement in performance over older and less exacting theories. However, most of the losses developing in the fluid as it flows through the rotor are chargeable to the peculiar behavior of the fluid along the channel walls. Our knowledge of boundary-layer behavior and secondary flow losses for grids or blades in close proximity is indeed scanty. Continued intensive research and development are necessary if we are to achieve maximum efficiency in the transfer of energy between the fluids and the rotor.

The problem of compressibility is yet to be dealt with satisfactorily. Mathematical formulation of the physical laws governing the flow of gases at high velocities are well known. Application of these laws, however, in their full effectiveness to turbine design is still in its infancy.

Methods are now in process of development for lesigning turbine blading according to these more xacting laws. Although they ignore the presence of oundary-layer effects, suitable judgment will achieve lesigns more favorable to small losses in the boundary ayer. At present they will predict the flow conditions nly for the design point. Recourse must be made to ruder methods to evaluate off-design conditions. These ff-design points are now being studied by graphically lotting the flow field. Introduction of some novel nechanical aids considerably reduces the human elenent and produces satisfactory results that are subtantiated by tests.

The gas turbine is continually being called upon to perate at higher and higher temperatures. Here the netallurgist must come to the rescue with new materials hat have superior physical properties at elevated temeratures. Some gains can be made by known methods f blade cooling but the complexity and losses brought nto play by some of these methods seems to emphasize he importance of metallurgical developments.

One of the most pressing needs at the present time is or an extended theory of elasticity that can be applied o the design of turbine blading. Our present knowledge equires that empirical methods be employed to study ibratory stresses. An imposing array of such problems re begging for talent to search out the solution and dvance the art of aircraft gas-turbine designs to new orizons.

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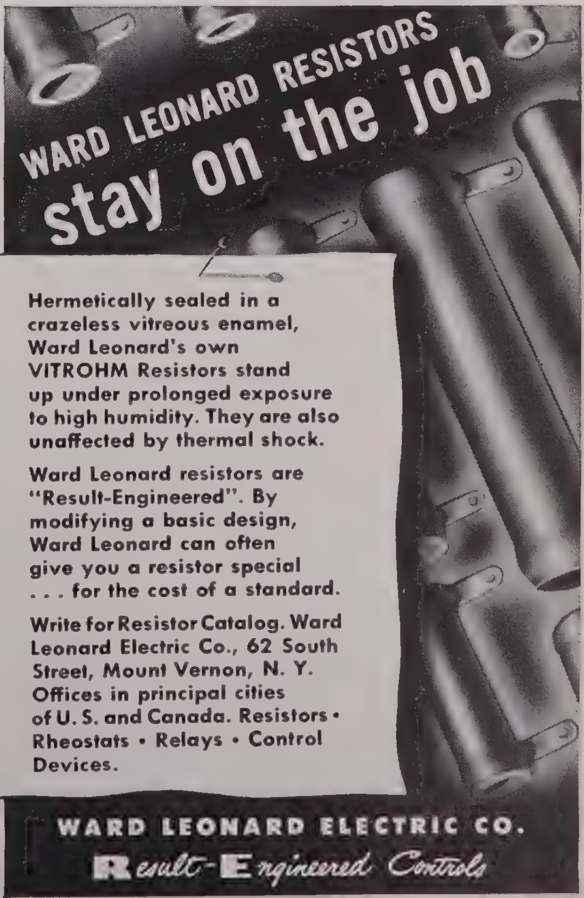
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POWER INDUCTANCE BRIDGE . . .

Equipment designed for flexibility and stability is used in testing large reactors under simulated operating conditions

Amos R. Kimball

By A. R. KIMBALL
Pittsfield Works Laboratory
General Electric Company

THE increased demand for large inductance iron-core reactors with limited test tolerances, for radar, electronics, and other allied fields, makes it highly desirable to speedily test reactors under simulated working conditions.

Several inductance measuring equipments are available with limited power capacities, but no unit investigated completely fulfilled the test requirements specified by products design engineers. Therefore, a special a-c inductance bridge and power supply were built for production testing of resonant charging reactors at rated voltage and currents. This article describes the design and construction features of the bridge and power supply..

GENERAL SPECIFICATIONS

The general specifications established by measurement and product design engineers were as follows:

(1). High accuracy over wide operating range (±0.5 percent with corrections). Range 1 to 1111 henrys; 1 to 100 Q factor

(2). Full indication and control of a-c/d-c current in the reactor windings during test. Power range: 0 to 8000 volts, 0.5 amp a-c; 0 to 500 volts, 0.5 amp d-c

(3). Direct reading indication of effective inductance and Q factor at 60 cycles

(4). A composite current wave plotted on a fluorescent indicating screen for visual study

(5). Indication of B-H loss factor plotted by same cathode-ray oscilloscope

(6). Self-contained power controls with safety interlocks, indicating lights, and meter compartment. The unit was to operate directly from 115/230 volts 60-cycle supply

The problem was one of combining accuracy, speed, and flexibility into a compact production test within specified limits.

High accuracy over wide operating range is more easily obtained with bridge methods than with some of the other types of measurement. Where self-balancing bridges[1] can be applied, speed and accuracy can be combined. Where the test specifications change frequently, or where balance for more than one quantity must be made simultaneously, manual balance types of bridges are more generally used. Since it was necessary here to balance for inductance and Q factor simultaneously, a manual balance type of bridge was selected.

The major components were designed or selected for good stability. Many components were individually adjusted to close tolerances in order to meet the over-all accuracy requirement. Allowances were made for the dissipation of heat generated in the high-resistance arms to avoid prohibitive resistance changes due to temperature coefficients. Shielding and isolated power circuits were provided to avoid spurious current errors often present in varying magnitudes.

Bridge methods frequently sacrifice speed for accuracy. Realizing this, the layout of the panel and controls was carefully planned for rapid, efficient operation. As a result, production tests are made with this equipment at the rate of about four minutes per point This includes making the connections, applying power adjusting the currents, obtaining a balance, removing power, and disconnecting the reactor.

The bridge was designed for flexibility of control Inductance and Q factor can be measured with on

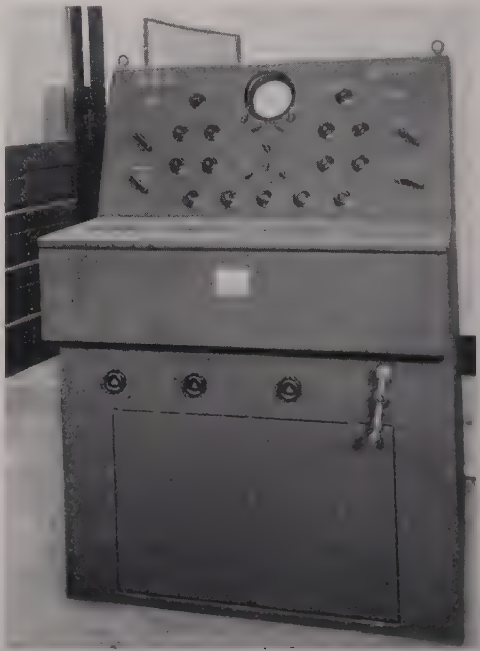

Fig. 1. Self-contained inductance bridge, of 1 to 1000-henry range and up to 0.5-amp 500-volt d-c, 0.5-amp 8000-volt a-c, for measurements of large iron-core reactors

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[1] "A Self-Balancing Capacitance Bridge," by A. H. Foley, *AIEE Trans.* vol. 66, Sept. 1947, p. 797-801.

This article is so paged that without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

without superimposed d-c currents in the reactor windings during test. Full control of a-c/d-c power from zero to maximum was made available by a carefully selected combination of tapped transformers, autotransformers, and rectifiers. The bridge has an inductance range of 1 to 1111 henrys and a Q-factor range of 1 to 100. The inductance range is covered in three bands having multiplying factors of 0.1, 1.0, and 10 respectively. The Q-factor range has only two multiplying factors, 1 and 10. The a-c voltage range is covered in five bands: 400, 800, 1200, 1600, and 8000 volts full scale.

The entire equipment is housed in a heavy-gauge fabricated steel cabinet, shown in FIG. 1. It is entirely self-contained, operating from a 115/230-volt 60-cycle 4-kva supply. It is a semiportable unit, although it weighs about 1500 lb, and some of the delicate components should be removed before any major transfer.

FUNDAMENTAL CIRCUIT

To test reactors under simulated working conditions, some method was necessary for producing the a-c/d-c currents in the reactor windings during test. There are several methods of applying mixed power to bridge networks. For the present application, a Hay's Bridge circuit⁽²⁾ was selected and modified as will be explained. Basically, the circuit is shown in FIG. 2(a), where, under balanced conditions

$$Z_1Z_3 = Z_2Z_4 \tag{1}$$

This may be expanded as shown in FIG. 2(b) where, under balanced conditions

$$(R_1 + j\omega L)\left(R_3 + \frac{1}{j\omega C_1}\right) = R_2R_4 \tag{2}$$

where, for these and subsequent equations:

Z = impedance

R = resistance in ohms

j = vector operator

ω = $2\pi \times$ frequency

L = inductance in henrys

C_1 = capacitance in farads (unless otherwise stated)

ρ = effective internal resistance in capacitor

l = compensating inductance in henrys

If Equation (2) is expanded and solved for L and R_1, these terms resolve into the following relationship

$$\frac{L}{R_1} = \frac{1}{\omega^2 C_1 R_3} \tag{3}$$

By definition, the Q factor of an inductor is the ratio of its inductive reactance to its resistance; therefore, in our nomenclature, we may write

$$Q = \frac{\omega L}{R_1} = \frac{1}{\omega C_1 R_3} \tag{4}$$

It should be noted that, to satisfy these equations, R_3 must represent all of the resistive component in the BD arm of the bridge. It could be expressed as $(R_{31} + \rho)$, as shown in FIG. 2(c), where ρ is the resistance due to the phase angle of capacitor C_{11} or $C_{11} + C_{12}$ (Fig. 3). Therefore, unless compensation is added to correct for the phase angle of the reference capacitor, R_{31} will not indicate Q factor directly.

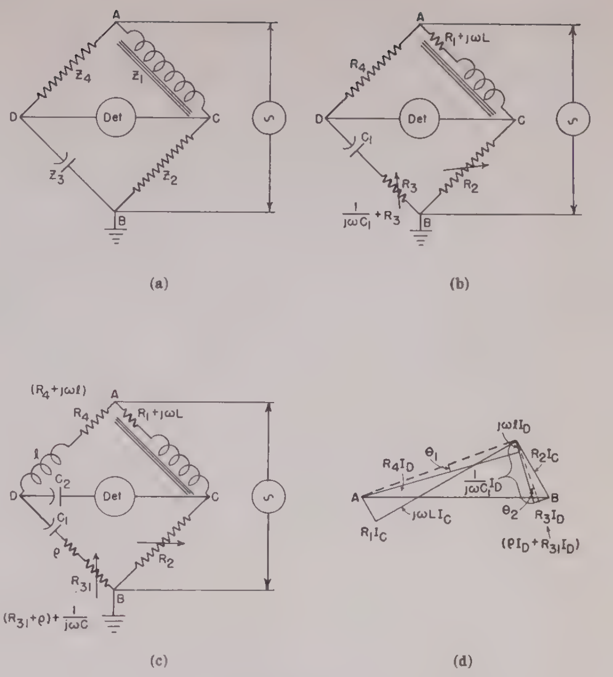


Fig. 2. Schematic elements of inductance bridge

(a). Basic circuit
(b). Expanded circuit
(c). Compensated circuit
(d). Vector relationships

One method of compensation which for all practical purposes corrects for this phase angle error is to insert the correct amount of inductance, represented by l, in the arm AD in FIG. 2(c). The effect is illustrated in the vector diagram in FIG. 2(d) where the amount of inductance l is made such that the phase angle of the arm AD is substantially equal to the phase angle of the capacitor C_1.

Thus $l = C_1R_4\rho$ and $\theta_1 = \theta_2$. Equation (2) now must be written

$$(R_1 + j\omega L)\left(R_3 + \frac{1}{j\omega C_1}\right) = R_2(R_4 + j\omega l) \tag{5}$$

and Equation (4) becomes

$$Q = \frac{R_4 + \omega^2 C_1 R_3}{(R_3R_4C_1 - l)} \tag{6}$$

Suppose now we substitute $(R_{31} + \rho)$ for R_3 Then,

$$Q = \frac{1 + \omega^2 C_1^2 \rho(R_{31} + \rho)}{\omega C_1 R_{31}} \tag{7}$$

Since for our case the term $\omega^2 C_1^2 \rho\ (R_{31} + \rho)$ is numerically much less than one, the actual Q factor very nearly equals

$$\frac{1}{\omega C_1 R_{31}} \tag{8}$$

⁽²⁾B. Hague: *Alternating Current Bridge Methods*, Sir Isaac Pittman & Sons Ltd., London.

Therefore, since R_{31} is a conductance decade it will indicate the Q factor directly.

In solving Equation (5) for R_1 and L, we obtain

$$L = \frac{R_2R_4C_1 + \omega^2C_1^2R_2R_3}{1+\omega^2C_1^2R_3^2} \tag{9}$$

$$R_1 = \frac{\omega^2C_1^2R_2R_3R_4 - \omega^2C_1R_2}{1+\omega^2C_1^2R_3^2} \tag{10}$$

Since for the present case C_1 is never more than 0.00001 farad, the term $\omega^2C_1^2R_2R_3$ in Equation (9) becomes insignificant and for all practical purposes L is represented by

$$L = \frac{R_2R_4C_1}{1+\omega^2C_1^2R_3^2} \tag{11}$$

Thus we have compensated the bridge for the phase angle of the reference capacitor so as to indicate Q factor directly without appreciably affecting the indication of inductance.

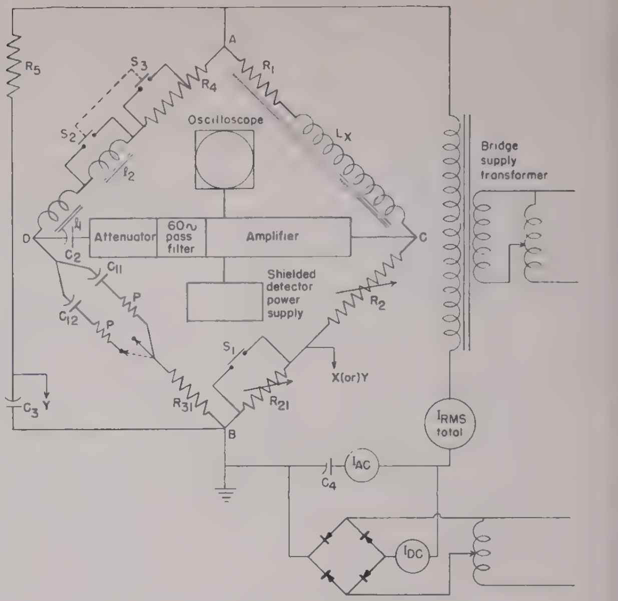


Fig. 3. Schematic details of compensated bridge circuit

BRIDGE CONSTRUCTION DETAILS

The fundamental bridge circuit, theoretically described in the preceding paragraphs, was supplemented and altered in the manner shown in FIG. 3 for our application. Each of the components shown was added to perform a very definite function, which will be explained. The additional features, however, did not alter the operating theory previously described. For example, R_{21} was a variable resistor inserted in the *BC* bridge arm for obtaining a voltage proportional to the reactor current. This voltage was applied to the vertical sweep of the oscilloscope for "ripple observation" and also as one component of the B-H plot. When the bridge was used, R_{21} was shorted by switch marked S_1 so that R_2 could represent the actual inductance in henrys. The resistor R_{21}, made variable to allow sensitivity control for wide ranges of reactor currents, was an 80-ohm 50-watt wire-wound rheostat with a shorting switch which closed automatically when the CRO FUNCTION dial was in position marked BRIDGE DETECTOR.

The inductance-indicator decades represented by R_2 were made up of ten (100+10+1+0.1)-ohm resistors plus a 0.1-ohm slide-wire vernier. These resistors were designed or selected to handle the total effective reactor current at any setting without overheating. The maximum effective current (0.5 amp each ac/dc) would be approximately 0.7 amp total $\left(\sqrt{(I_{\text{rms}})^2+(I_{\text{dc}})^2}\right)$. At full dial setting and maximum effective current, the heat to be dissipated by these decades would be approximately 500, 50, 5, and 0.5 watts respectively. The two lower units are air-cooled panel-type decades. The two larger decades were made up of Advance wire wound noninductively on Textolite cards. These cards were assembled with the multiplier resistor cards R_4 and the Q-factor-resistor cards R_3 in a tank of oil. Under maximum working conditions these resistors dissipate approximately one kilowatt; and to prevent the oil temperature from rising too high, water-cooling coils were installed. A thermostat was also installed in the oil to open the "safety circuit" if the temperature exceeded 80 C. There are eighty-nine 2-in. by 8-in. wire-wound cards in all, each one carefully adjusted to close tolerance. The wire sizes were carefully chosen and each card was limited to 10 watts or less.

The Q-factor resistance (R_{31} in FIG. 3) consists of four conductance decades and a vernier made up of a 25,000-ohm fixed resistor and a 250,000-ohm volume control in series. The conductance decades employed four resistors which were used singly or in parallel to obtain the ten steps per decade. Table I illustrates the manner in which this is accomplished. The decades were marked "Hundreds," "Tens," "Units," and "Tenths" covering an inverse resistance range of 2652 ohms, at Q-factor setting of 1, to a value 26.5 ohms, at a Q-factor of 100. These values are nominal values with the multiplier setting of one in both cases. A Type KX 642 gap-protector tube was connected across resistance R_{31} to prevent high voltage from appearing at the *D* point of the bridge in case R_{31} failed or was opened accidentally. Nominally, the current in the Tenths decade and the vernier unit would be very small; but, should the first three dials be accidentally placed on zero, the total current in the *ADB* arm would have to be borne by the Tenths decade and the vernier in parallel. Quite obviously this would be an unusual condition but it is possible and therefore the protective device was necessary for safety.

The reference capacitor C_1 (C_{11} and C_{12} in FIG. 3) is made up of 40 specially treated 1-μf 300-volt units. They were carefully selected for stability and nominal values. They are connected in series-parallel arrangement to obtain two 600-volt sections. One section (C_{11}) is rated 1-μf 600-volts and the other section (C_{12}) is rated 9-μf 600-volts. It will be seen in FIG. 3 that C_{11} is permanently connected in the bridge arm *BD* while C_{12} is switched in parallel to give a total of 10 μf or a

10 to 1 ratio. The switching is so arranged that for the lowest two ranges of the bridge only C_{11} is used and C_{11} and C_{12} are both used for the highest range.

Fig. 3 shows two compensating inductances l_1 and l_2 in series, one being shorted out when switching ranges of R_4. The reason for this is to satisfy the equation $l=C_1R_4\rho$. It will be seen that in switching from low to medium range R_4 changes from 10,000 to 100,000 ohms. Therefore the value of compensating inductance must be changed 10 to 1. For example, assuming the power factor of C_{11} and C_{12} is 0.3 percent and the values of R_4 are 10,000 and 100,000 ohms, the calculated values of $l=C_1R_4\rho$ would be:

Low range,
$l_1=0.000001\times10^4\times(2652\times0.003)=80$ millihenrys

High range,
$l_1+l_2=0.00001\times10^5\times(265.2\times0.003)=800$ millihenrys

To make easier switching, l_2 can be made 720 millihenrys and put in series with the 80 millihenrys needed for l_1.

To cover the specified working range of the bridge with 1 and 10 microfarads in the *BD* arm, it was necessary to have 10,000 and 100,000 ohms in the R_4 arm. These were made up of the previously mentioned cards immersed in oil, 7 cards in one bank amounting to 10,000 ohms and 33 cards in another bank for an additional 90,000 ohms, making a total of 100,000 ohms together. The switch S_3 shown in Fig. 3 shorts out the 90,000 ohms when the lowest bridge range is used. A high-voltage shorting switch is required because when it is opened, the voltage drop across the switch terminals could be as high as 7000 volts. The insulation resistance across this switch must not degrade the 90,000 ohms used as part of R_4. This switch was solenoid operated and controlled by an auxiliary finger on a special switch marked Multiplier on the panel shown in Fig. 1. The special switch is really two switches in one. The first position is a "dead" or dummy position. In the second position, circuit is made to remove the shorts across the l_2 and the 90,000-ohm section of R_4; in the third position the second condition is maintained and the 9-μf capacitor C_{12} is in parallel with C_{11}.

POWER CONTROLS

The supply circuit, shown in Fig. 4, is a 4-kva 115/230-volt 60-cycle three-wire source. The power is supplied through two three-wire magnetic contactors in series. The operating coils of these contactors are paralleled and wired in series with several safety interlocks and control switches so that the main power to the bridge can not be applied unless all the safety gates etc. are closed. An auxiliary finger on each of these contactors is wired in a pilot-light circuit so that, when the contactors are "on," the area pilot lights and one signal light marked Safety Circuit on the berth will be lighted.

One pilot light, a convenience outlet, and interior lights are connected ahead of these contactors so that interior inspection and repairs can be made without bridge power "on." The pilot light marked Berth Power on the panel also indicates when power supply to the berth is "on" or "off."

The a-c power feeds through a three-pole single-throw SB1 switch marked AC Power on the panel. This energizes two variable autotransformers, which in turn feed a multiple-tapped transformer and a series control transformer. Two pilot lights marked AC Power on the panel indicate when this switch is closed. Two lights are necessary to indicate whether a fuse in one of the outside lines is blown. The large autotransformer is operated manually by the "ball-crank" shown at the lower right front of the berth (Fig. 1). The fine control is the next control knob to the left. With the various combinations of autotransformers and tapped transformers, five ranges of voltage are available. These are connected to a five-point selector switch marked AC Voltage Range on the panel. The load side of this switch is connected to the primary of the special bridge transformer which has a step-up ratio of 35 to 1.

The special transformer is designed to handle d-c current in the secondary winding without seriously affecting the excitation of the core. The maximum secondary voltages available for bridge excitation are 400, 600, 800, 1200, and 8000 volts. To avoid confusion, two a-c ammeters are shown in Fig. 3; actually only one is used. The a-c ammeter is switched to read "Total RMS" or "AC only" as indicated by a switch marked AC Ammeter Position at the left of the panel shown in Fig. 1.

The d-c power is obtained by rectification from one side of the a-c supply immediately following the magnetic contactors. The switch provided for control is a two-pole single-throw SB1, marked DC Power, on the left of the panel. A corresponding pilot light was provided. Coarse and fine controls were furnished by variable autotransformers as for the a-c control. A voltage stabilizer was installed ahead of the variable

Table I

Q-FACTOR DECADE ARRANGEMENT

Dial Setting	0	1	2	3	4	5	6	7	8	9	10
Unit or parallel combinations		1	2	3	4	1 4	2 4	3 4	1 3 4	2 3 4	1 2 3 4
% Unit Resistance	00	100	50	33.33	25	20	16.67	14.28	12.5	11.11	10.0

(Nominal unit resistance, 2652 ohms)

autotransformers to overcome transient disturbances corresponding to the time constants present in the bridge circuit and the rectifier itself. The rectifier was a conventional full-wave rectifier employing two 866 mercury rectifier tubes. The filter circuit employed two 20-henry chokes and a 10-μf capacitor with suitable discharge resistance for safety. The rectifier has about 0.01 percent ripple.

The d-c current was connected to the bridge circuit across a 40-μf by-pass capacitor shown in FIG. 3 as C_4. The positive side of the output is connected to the grounded point of the bridge and the negative side through a d-c ammeter to the center point of a single-pole double-throw SB1 switch marked AC AMMETER POSITION. Depending on the position of this switch, the d-c current is made to pass through or around the a-c ammeter. (The switch is not shown in FIG. 3.)

The instruments are housed in a compartment below the control panel (FIG. 1). Four viewing windows are provided in the hinged cover. The interior has practically shadowless illumination from two 30-watt fluorescent lights mounted under the cover. There are two interlock switches which are in the series interlock circuit for operator protection. When the cover is opened, power is removed from the a-c/d-c circuits.

BRIDGE BALANCE DETECTOR

The balance points of the bridge (*CD*, FIG. 3) were above ground potential under operating conditions and therefore the amplifier and cathode-ray oscilloscope had to be carefully isolated and shielded to prevent spurious currents from interfering with true balance. A specially shielded 250-watt isolating transformer having approximately 1-to-1 ratio was designed and built to energize the amplifier and oscilloscope. This transformer had less than two micromicrofarads of effective capacitance between windings. Shielded leads were used entirely in interconnecting the amplifier, oscilloscope, and associated equipment of the detector circuit. A specially shielded gang selector switch was designed and built for switching the oscilloscope circuit. This switch was marked CRO FUNCTION.

The amplifier is a two-stage pentode amplifier tuned to 60 cycles and furnished with a regulated d-c power supply. Filter networks of the RC type preceded the grid of the first tube to filter out the second- and third-harmonic components which are frequently present in the unbalance signal for this type of bridge. The output of the amplifier was connected through the selector switch to the vertical-axis amplifier of the oscilloscope.

The cathode-ray oscilloscope was supported in an insulated cradle about two inches back of the control panel, and all of the normal controls were extended through the front panel and isolated both for operator protection and measuring reasons. The amplifier chassis was insulated from ground likewise to avoid leakage-current interference.

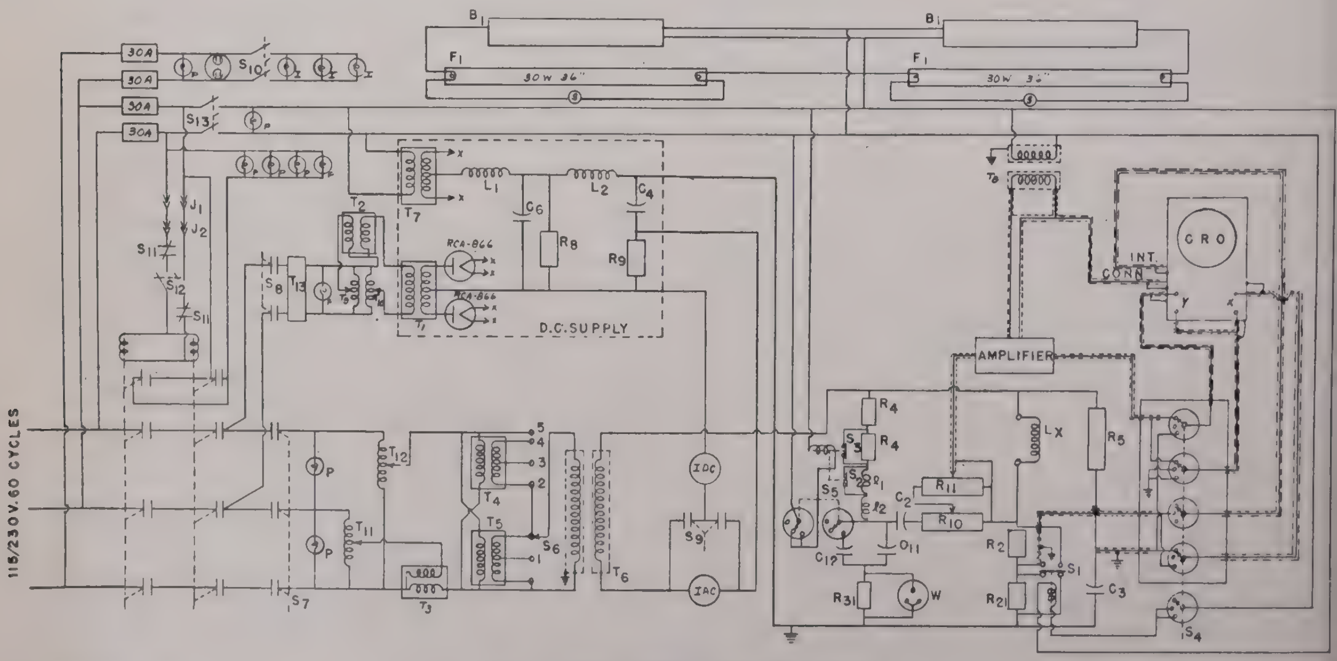


Fig. 4. Circuit diagram of inductance bridge

S_1: Shorting Relay
S_2: Shorting Relay
S_3: Shorting Relay
S_4: Selector Switch
S_5: Range Multiplier Switch
S_6: Voltage Range Switch
S_7: AC Power Switch
S_8: DC Power Switch
S_9: Ammeter Switch
S_{10}: Interior Light Switch
S_{11}: Cover Safety Switches
S_{12}: Safety Control Switch
S_{13}: Switch for Amplifier, CRO Power, and Instrument Illumination
T_1: Plate Transformer
T_2: Fine Control Transformer
T_3: Fine Control Transformer
T_4: Step Down Tapped Transformer
T_5: Step Down Tapped Transformer
T_6: Special Bridge Supply Transformer
T_7: Filament Transformer
T_8: Special Shielded Transformer
T_9: Autotransformer
T_{10}: Autotransformer
T_{11}: Autotransformer
T_{12}: Autotransformer
T_{13}: Voltage Stabilizer
R_2: 10(100+10+1+.1)+.1 Ohm
R_{21}: 80 Ohm 75 Watt Rheostat
R_{31}: 4 Conductance Decades and Vernier
R_4: Multiplier Resistor
R_5: Voltage Divider Resistor
R_8: Discharge Resistor
R_9: Discharge Resistor
R_{10}: 50 M Attenuator
R_{11}: 50 M Attenuator
C_2: Blocking Capacitor
C_3: Voltage Divider Capacitor
C_4: By-pass Capacitor
C_6: Filter Capacitor
C_{11}: Reference Capacitor
C_{12}: Reference Capacitor
Lx: Reactor to be Tested
L_1: Choke
L_2: Choke
l_1: Compensating inductance
l_2: Compensating inductance
W: Type KX642 Protector Tube
I: Interior Lights
B_1: Fluorescent Ballasts
F_1: Instrument Fluorescent Illuminators
J_1: Safety Gate Switches
J_2: Rear Door Safety Switches

A blocking condenser C_2 (FIG. 3) was used to keep the d-c from the detector circuit. Two 50,000-ohm wire-wound attenuators were installed between this and the detector amplifier. One was used to set the range of sensitivity suitable for a particular line of units to be tested and the second used for final full-range operation. This enabled the operator to test more rapidly once the range setting was established for the first reactor of a given line.

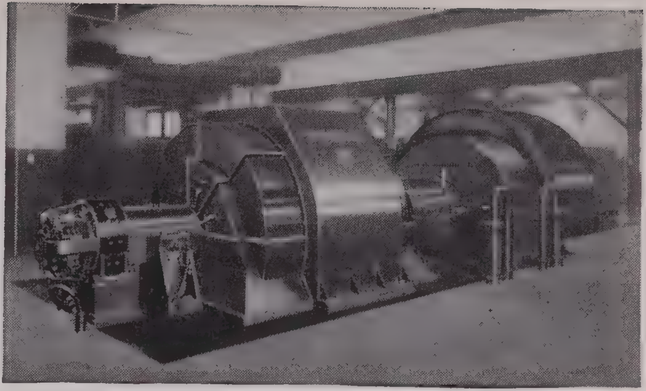
RIPPLE OBSERVATION AND B-H PLOT

For ripple observation, a voltage drop across R_{21}, which is proportional to the current in the reactor under test, is connected to an internal point of the oscilloscope through the special switch marked CRO FUNCTION. The reason for connecting this internally is to by-pass the a-c amplifier in the oscilloscope to make it responsive to the d-c as well as the a-c component of the signal. The amplitude is controlled by R_{21} because, in connecting beyond the a-c amplifier of the oscilloscope, the Y-axis gain control is out-of-circuit. The position controls are still effective and may be used in the normal manner. It is the usual custom in the measurement of resonant reactors to make the peak a-c test current equal to the d-c current. For the present case, instruments were always used to determine the setting of these currents, but the so-called ripple observation makes a very convenient visual check. It serves also as a visual check on the wave shape of the test current.

The B-H plot, so-called, is a Lissajous figure produced on the oscilloscope screen from components proportional to the reactor current and its applied voltage. This statement is not entirely true since in practice the voltage divider composed of C_3 and R_5 is placed, as in FIG. 3, across the AB points of the bridge instead of across the test reactor. This gives a signal voltage which differs by less than five per cent in magnitude and not more than two degrees in phase angle from what it would be if the divider were placed across the reactor. By placing the divider in the manner shown it does not interfere with the accuracy of the other bridge functions. The voltage divider shown in FIG. 3 is composed of a one-microfarad capacitor C_3 and a one-megohm resistance R_5. The junction of these elements is connected to the vertical oscilloscope amplifier and the junction of resistors R_2 and R_{21} is now connected to the horizontal amplifier.

This gives a Lissajous figure oriented in the usual manner of plotting B-H curves. The Lissajous figure which is obtained in this manner is indicative of the loss in the reactor. While it is not a quantitative measure, it will give indication of shorted turns and low Q factors.

The author wishes to acknowledge the generous assistance of engineers of the Power Transformer Engineering Division in establishing the specifications and in the design of the special transformer used in coupling to the bridge; and also the assistance of A. H. Foley and S. C. Leonard of the Laboratory.



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HIGH LIGHTS AND SIDE LIGHTS

Increasing Turbojet Thrust

Means for increasing the thrust, or driving force, of aircraft jet engines as much as 100 percent were discussed at the annual aviation conference of the American Society of Mechanical Engineers in Dayton (O.).

One means, called exhaust reheat, raises the temperature and velocity of the exhaust gases by burning extra fuel in the engine's exhaust system.

In this way, the thrust output of a modern, widely used, aircraft jet engine can be increased as much as 40 percent at takeoff, or 100 percent under high-speed and high-altitude conditions. Speed-thrust augmentation methods now under development improve the takeoff and low-speed acceleration characteristics of jet planes.

Another scheme described for increasing the turbojet's thrust involves injecting a mixture of water and alcohol into the engine's combustion system. The steam thus formed adds to the thrust produced by the normal flow of hot gas.

The high rate of fuel consumption which results from these thrust-boosting methods limits augmented operation to short periods. However, the higher thrust is required only for takeoff or other infrequent and short-duration flight conditions. The added exhaust, obtained by burning additional fuel in the engine's exhaust system or by adding a water-alcohol mixture to the air passing through the engines, is realized for less weight than if it were to be obtained through the use of a larger and heavier turbojet.

Motorized Unit Projects Antibiotic Aerosol

A motorized unit to provide air pressure for the projection of antibiotic aerosol has been perfected and is now in production.

The unit, called the Vaponefrin aerosol motor unit, is manufactured for use in medical offices, hospitals, clinics, homes, laboratories, and operating rooms where oxygen formerly has been used as a means of pressure.

Demonstrating the use of the Vaponefrin aerosol unit. Two complete motor units, one finished in white and one in black, are in the foreground.

In the unit the motor, by means of an eccentric, actuates a rubber diaphragm which delivers the air pressure. The air pressure operates the various nebulizers used for inhalation therapy and for the projection of antibiotics for respiratory diseases and infections such as bronchiectasis, lung abscess, bronchitis, infective asthma, and allied respiratory ailments. A suction side makes possible the use of the Vaponefrin for aspiration.

The unit-bearing motor driving the device is totally enclosed and lubricated for life, thereby making it possible to deliver plain, pure air, without the odor of oil encountered in piston- and rotary-type air pumps.

X-ray Diffraction for Quantitative Analysis

Broad new fields of application for x-ray diffraction in the identification and quantitative analysis of unknown materials have been opened by a high-precision, high-output machine which, with its many attachments, was shown in an exhibit and described in two papers read before the International Congress of Crystallography held at the Harvard University Department of Mineralogy July 28 to August 3.

One attachment, the fluorescent analyzer, greatly extends the range of composition of materials which can be analyzed, in comparison with that possible when using optical spectrometers.

Another group of attachments, which make possible the direct recording of x-ray intensities on a continuous strip of chart paper, save hours of laboratory time by

Summer job of this young electrical-engineering student was the taking of photographic records and electrical measurements of lightning striking the Empire State Building in New York (described in High Lights, September). Here he adjusts camera speeds and reports to a dictating machine the nature and time of each lightning stroke

The Empire State Building, focal point of the annual lightning measurements, is a lightning rod for all buildings within a one-third-mile radius. Its steel-structured frame provides a good ground for electric charges forming in the area, protecting everything in the Empire State Building itself and the surrounding buildings revealing both the angular placement of the characteristic lines of materials and their relative intensities.

The new unit couples, for the first time, precision control of x-ray output with high x-ray intensity. Hitherto, such accuracy could be achieved only at the expense of intensity. This was reflected in the comparatively low milliamperage at which such machines were operated. Now, accurately controlled x-ray diffraction beams of higher intensity can be produced. The tube can be operated at milliamperages up to 30.

X-ray intensity of the unit is controllable and reproducible to an over-all accuracy of 0.5 percent. The accuracy is accomplished by controlling the x-ray tube voltage to within 0.1 percent and the tube current to within 0.02 percent.

Because higher intensity makes it possible to direct a comparatively narrow beam of x-radiation from a very narrow source to the specimen under observation, both the resolution of spectral lines and the speed of analysis are greatly increased.

The high output is achieved through the use of a new sealed-off diffraction tube with three pure beryllium windows, which are within one inch of the end and the focal spot of the tube. Carefully controlled focal-spot size and distribution also contribute to the output. The tube is excited from a high-voltage transformer and full-wave rectifier rated at 50 kv peak, 50 ma continuously—providing a capacity beyond that of tubes now available, in anticipation of future improvements.

As a result of the precision mechanical construction, the spectrogoniometer reads angles directly down to 0.01 deg.

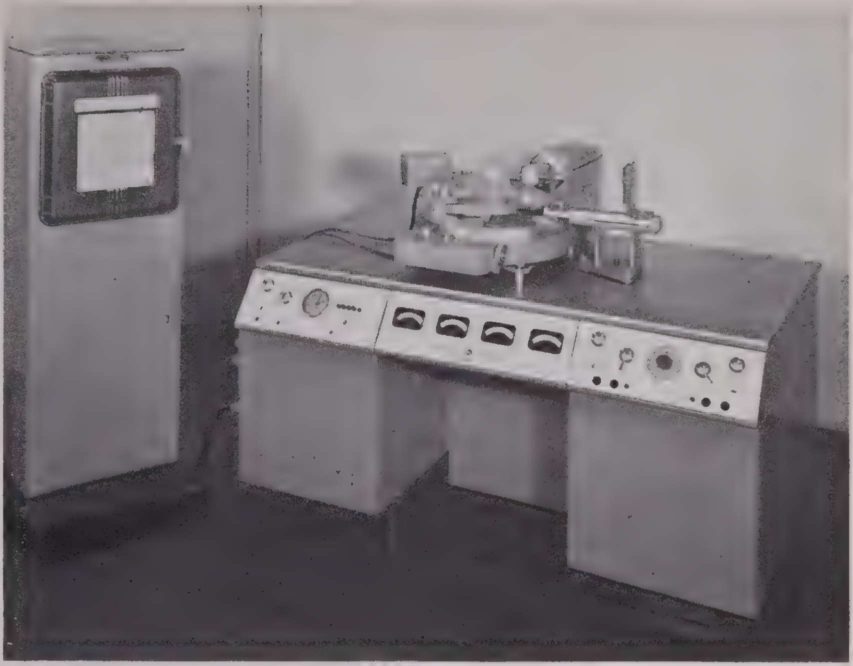
The new instrument may be used, with different attachments, for three different purposes:

One of these is for the direct measurement of x-ray diffraction intensities through the use of a Geiger-Mueller counter in combination with a rate meter, scaler, and chart recorder. The counter is capable of counting diffracted x-ray quanta lineally over a longer range of intensities than ever before possible. The rate meter, which is matched with the strip-chart recorder, has a logarithmic response over three decades.

The second manner in which the unit may be used is as a fluorescent x-ray spectrometer, employing a focusing crystal analyzer.

Third, it may be employed, with x-ray-sensitive film, as a conventional x-ray diffraction unit.

Particularly notable is the radical departure in the external design. The tube mounting permits quick and accurate change of x-ray tubes. Either the direct-recording apparatus or the fluorescent analyzer can be used simultaneously with the precision track for conventional diffraction radiographic cameras.



Apparatus for direct measurement of diffracted x-ray intensities. All parts but the chart recorder are incorporated into a desk-type console, with the top free from obstructions around and under the tube

The x-ray quanta count scaler is used to measure the time required to produce a preselected number of counts so that probable accuracies within 2, 1½, 1, ¾ and ½ percent can be preselected.

A self-contained x-ray tube cooling system eliminates plumbing and operational difficulties associated with conventional tap-water systems.

Sample holders are provided for reflection and transmission techniques; also a sample spinner for fractional gram quantities of material and an integrating flat sample spinner for medium grain size samples.

The diffracted beam monochromator provides for optimum contrast of diffracted intensity over brackground.

Measurement Accuracy of Five Cycles per 1,000,000

An instrument has been developed which can detect the difference between 1,000,000 and 1,000,005 electrical impulses per second.

This "AM station monitor" is designed to measure the over-all performance of standard radio broadcasting stations. It can tell radio engineers when a station is broadcasting off its assigned frequency by as little as five cycles per million.

Using a new type of electronic circuit, the monitor is reported to measure the broadcast frequencies with two times the accuracy required under present Federal Communications Commission regulations.

In addition to measuring frequency, the monitor keeps radio engineers constantly informed as to the amplitude of the waves being broadcast and the amount of power being transmitted. This is believed to be the first unit to contain in one package all of the major instruments for keeping a constant check on radio broadcasts. The new monitor, moreover, no larger than an egg crate, takes up about half as much space as equivalent equipment now in use.

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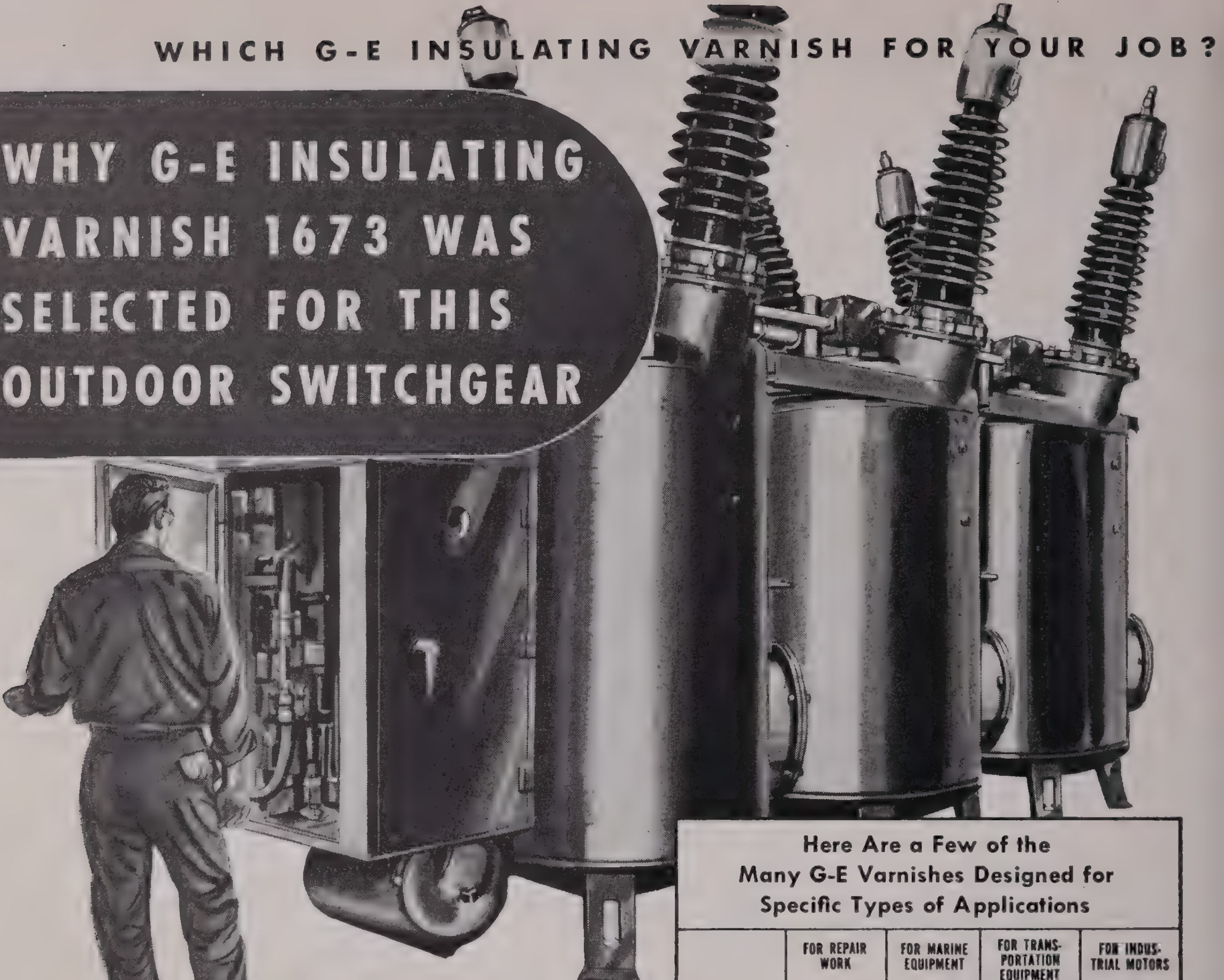

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RESISTANCE TO MOISTURE	EXCELLENT	GOOD	GOOD	EXCELLENT
RESISTANCE TO ALKALI	EXCELLENT	GOOD	FAIR	EXCELLENT
RESISTANCE TO ACIDS	EXCELLENT	GOOD	GOOD	EXCELLENT
RESISTANCE TO SALT WATER	EXCELLENT	EXCELLENT	GOOD	EXCELLENT
PENETRATION	GOOD	GOOD	EXCELLENT	GOOD
TOUGHNESS	EXCELLENT	FAIR	GOOD	EXCELLENT
HIGH TEMPERATURE AGING	EXCELLENT	GOOD	EXCELLENT	GOOD
FLEXIBILITY	EXCELLENT	GOOD	GOOD	FAIR

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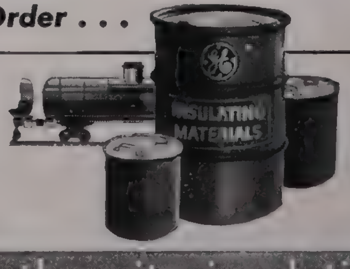

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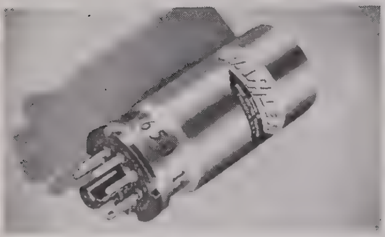
NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM



Time-delay Unit

Volt-Ohm-Milliammeter

Shielded Capacitor

A new shielded multiple-section capacitor, Type MC-9A63, designed for use where chassis space is at a premium. Its case construction of four completely shielded sections makes this capacitor especially useful in applications where circuits must be isolated.

Although a midget in size, this capacitor is claimed to give trouble-free operation under severe conditions. The outstanding features include its design to JAN-C-25 performance characteristic E; exceptionally small base dimensions for a four-terminal capacitor; ceramic-kovar solder-sealed terminals; hermetically sealed for operation from minus 55 C to plus 100 C; and each capacitor section electrostatically shielded from others.—*Cornell-Dubilier Electric Corp. South Plainfield, New Jersey.*

Tube Transformers

Flickerless performance; quiet, low operating temperature; and long service life are achieved in the new Felco luminous-tube transformers. The design of the coil and its placement minimize electrical stresses, and direct short leads prevent destructive corona action.

The design makes provision also for the following features:

(1) Extra mica throughout

(2) Coils specially processed to exclude any possibility of moisture

(3) Midpoint grounding for balanced design, with larger wire in both primary and secondary coils

(4) Shunts integral with core

(5) Double-sealed case with beaded cover edge for weather protection

(6) Shockproof insulator caps quickly attached in any one of four positions

(7) Black-crackled baked-enamel finish with cadmium-plated metal parts.

—*The Forest Electric Co., 7216 Circle Ave., Forest Park, Ill.*

Time-delay Unit

The new Tarrytron time-delay unit with settings available from one second to two minutes' duration has a wide application in aircraft, scientific, and industrial fields. The unit has been vibration-tested and is stable in operation when subjected to as high as 12 g's acceleration. The heater currents can be ranged from 6 volts to 115 volts, a-c or d-c. It is furnished with an octal plug-in base, interchangeable with similar time-delay units.

Where continuous duty and heavy currents are encountered, this unit is supplemented with a miniature relay so arranged that it cuts out the unit as soon as it has performed its delay functions; the load currents are then carried on snap-acting relay contacts sufficiently heavy for severe service conditions.—*DiaPHlex Division, Cook Electric Co., Chicago, Ill.*

Volt-Ohm-Milliammeter

Model No. 1221 volt-ohm-milliammeter is equipped with rotating dials and is designed as a high-sensitivity instrument suitable for television, radio, and industrial testing. The Roto-Ranger principle eliminates the confusion of numerous scales and multiplying factors common to ordinary multirange testers. Its operation is simple; as the selector switch is moved to the range desired, the proper scale for that range is brought into place behind the meter window. There are no cramped calibrations; each scale is large and full sized, as it would be for a separate instrument.—*Simpson Electric Co., 5200-18 West Kinzie St., Chicago 44, Ill.*

Flexible Tool

Flex-O-Pic, a specialty tool for hard-to-reach parts and places, is a precision-made acid-proof cadmium-plated product. The shaft, a flexible cable such as is used in speedometers and dental equipment, is encased in a flexible housing with expanding and retracting fingers which enable it to reach in and take a tight hold on an object. It has enough flexibility to work around corners or S-turns. Especially invented for tricky service jobs, the tool would be useful in radio and battery shops, home workshops, airplanes, boats, and cars. The tool can be taken apart and cleaned, and it is available in any size shaft for specific problems.—*Emco Enterprises, Inc., 6750 Stony Island Ave., Chicago 49, Ill.*

D-c–A-c Chopper

A new d-c and a-c chopper for use with thermocouples, strain gauges, and other low-level equipment to convert pure d-c into either pulsating d-c or a-c so that the output of these devices may be amplified with a-c amplifiers rather than d-c amplifiers. By use of information gained in the field of ultrahigh-speed relays the chopper is made to cover frequencies from 10 to 500 cycles, so that it is possible to use the new choppers either on 60 cycles, as previously, or on 400 cycles in aircraft.—*Stevens-Arnold Inc., 22 Elkins St., South Boston 27, Mass.*

Voltage Stabilizers

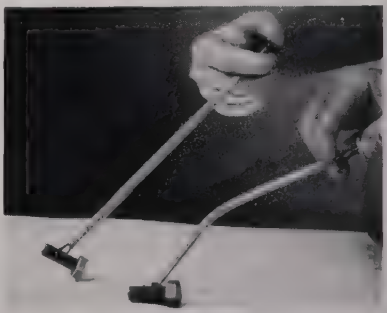
Three new voltage stabilizer units hav been added to a standard automatic voltag stabilizer line. The new units are 115-vol 60-cycle designs in 15-, 25-, and 50-va ratings. They provide a steady output o 115 volts (±1 percent for fixed unity-power-factor loads) with input voltages rangin from 95 to 130 volts. Their low case heigh and small size make them particularly suitable for shallow-depth installations.

Other features include totally insulate construction (which is necessary wher isolation is required between primary an secondary circuits) and universal-typ leads, a feature which adapts these units t a variety of wiring and mounting arrangements.—*General Electric Co., Schenectady 5 New York.*

Contact Metal

A new electrical contact metal name Fasaloy 99 has the desirable properties o fine silver plus a substantially higher "no weld" current value. Tests show that th contact surface resistance is no higher tha that of fine silver, even when the contact are subjected to high temperatures or hydrogen sulphide atmospheres. Tests also show these contacts will make and break resistance-load circuits of as high as 25 percen more current than will silver, without failur due to sticking or welding.

The metal appears to be particularly wel suited for uses where relatively low operating pressures and high temperatures are encountered, and where circuits of relativel high amperage are made and broken.—*Fansteel Metallurgical Corp., North Chicago Illinois.*



Flexible Tool

D-c–A-c Chopper

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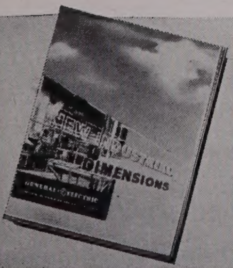

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Ball Bearings—Comprehensive specifications on more than 40 types and sizes of standard miniature ball bearings including radial, super-light, pivot, angular contact, and thrust bearings. Data are given on designs, variations, lubrication, weights, applications, and other items of interest to designers of precision mechanisms. Catalog No. 49. Eight pages.—*Miniature Precision Bearings Inc., Keene, New Hampshire.*

Connectors and Fittings—Comprehensive in contents, a wide assortment of Army-Navy connectors are presented in a well-arranged simplified manner. Each page gives specifications as to number of contacts, current or wire size, voltage or contact spacing. Information for selecting fittings is indexed in numerical sequence. Catalog A-1. Seventy-five pages.—*American Phenolic Corp., Chicago 50, Ill.*

Drafting Machines—Six main characteristics of a new stainless-steel drafting machine are illustrated and described. Drafting board units of the vertical and horizontal types are also included. Bulletin 6-48 and Supplement 7-48. Seven pages.—*Emmet Mfg. Co., Waynesboro 2, Pa.*

Drill Unit—The way to faster and more accurate economical production drilling is the subject of a folder describing the Model 250 drillhead, an automatic tool for single and multiple-tool drilling that is simple in design, soundly engineered, and precision built.—Four pages.—*Cleveland Republic Too Corp., 1265 Union Commerce Bldg., Cleveland, Ohio.*

Finishing and Deburring—This two-color manual illustrates and describes the Roto-Finish method for mechanical finishing and deburring, covering the four principal procedures which make up the process: deburring and grinding, polishing, britehoning, and coloring. The booklet also gives a step-by-step account of how the method operates, types of parts to which it is best applied, and formulas governing mixtures of chips and compounds. Sixteen pages.—*The Sturgis Products Co., Sturgis, Mich.*

Gear Tester—Various models of the Parkson gear tester in sizes ranging from 4½-in. to 36-in. capacity are described in this folder. The text also points out how rapidly gear faults and errors can be determined by the use of these testers. Ten pages.—*George Scherr Co., Inc., 200 Lafayette St., New York 12, N. Y.*

Lighting—A planned lighting guide in the form of a catalog intended to remove the guesswork from lighting installations. Designed for use by architects, lighting engineers, and electrical contractors, it contains information for successful application of fluorescent lighting, including candlepower distribution, coefficient of utilization and footcandle-level charts, dimensions, specifications, etc., complete with illustrations. Catalog No. 31-F-23. Forty pages.—*The Spero Electric Corp., 18222 Lanken Ave., Cleveland 19, Ohio.*

Metal Products—About 200 standard products made of Monel, Inconel, or nickel for corrosive and high-temperature service are described and illustrated under 47 general classifications. These include balls, floats, nails and bolts, pickling slings and hooks, thermostat parts, pipe and pipe fittings, gaskets, valves, cathodes, etc. Titled "Standard Specialties." Twenty-four pages.—*International Nickel Co., Inc., 67 Wall St., New York, N. Y.*

Permanent Magnets—In addition to the various permanent magnet holding assemblies, this bulletin describes metallurgical products including cast and sintered alnico, cunife, cunico, vectolite, and silmanal. Special alloys such as the thermistors and hevimet are also covered. Bulletin No. CDM-12. Eight pages.—*Chemical Dept., General Electric Co., Pittsfield, Mass.*

Switch and Bus Insulators—A new template for use by draftsmen and engineers containing outline drawings of all standard outdoor-type switch and bus insulators in scales ranging from 1½ in. to the foot to ¼ in. to the foot. When placed under the drawing or tracing, the outlines of the insulators can be drawn quickly and easily, saving hours of drafting time.—*Locke, Inc., P.O. Box 57, Baltimore 3, Md.*

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BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW for domestic delivery; none sent on approval.)

FLUORESCENT AND OTHER GASEOUS DISCHARGE LAMPS

William E. Forsythe and Elliot Q. Adams—Murray Hill Books, Inc., New York. 1948. 304 pp. $5.00.

The authors of this book, who are well known for their own excellent experimental work and their publications on tungsten lamps, have here taken a new role in bringing together and editing a great mass of material from many places, about all types of fluorescent and gaseous-discharge light sources. There are very few topics which pertain to these general fields that the reader will not find discussed at least briefly, from the theory of the atom to the television tube, scotophors, and the icaroscope.

About 200 pages of the book are devoted to the fluorescent lamp, covering as general subjects the characteristics of the mercury discharge in the lamp, the properties of phosphors, electric circuits and starters for operating fluorescent lamps, and the color characteristics of various lamps. The authors attempt, as far as possible, to develop each subject from fundamental principles; thus, in spite of somewhat poor integration of material and a noticeable lack of references to original articles in some sections, the book will be very useful to those who are looking for something more than engineering tables and curves. In the two short final chapters there is a treatment of the operation and light output of special arcs and flash lamps.

For those who have questions concerning the principles of operation of the fluorescent lamp in particular, this book will be a handy reference, covering a surprisingly wide range of material in its relatively small number of pages. FRANK J. STUDER

PRINCIPLES OF SERVOMECHANISMS

Gordon S. Brown and Donald P. Campbell—John Wiley & Sons, Inc., New York. 1948. 414 pp. $5.00.

Knowledge of closed-loop, or feedback-type, control systems has improved considerably since the days when equipment was shipped from the factory with extra capacitors and resistors provided for the installation engineer to connect in various ways in an effort to "anti-hunt" the system. This book presents the modern techniques of closed-loop system analysis and synthesis which were developed behind the curtain of military security during the war years. The reader is carried far beyond mere stability analysis to a study of design tools usable for creating systems to meet definite specifications. Intended as a textbook for senior and graduate students, the book is written so consistently from a realistic design point of view that the practicing engineer will find it of great interest.

Closed-loop systems are studied from the two complementary viewpoints of transient response and steady-state sinusoidal response. The transfer-function representation of systems in terms of various loci plots is presented as an effective synthesis tool. A relatively quick approximate method is given for determining transient response from the steady-state response. There are chapters on response to load disturbances and on laboratory measuring techniques.

The book is highly readable. The authors are to be commended for their effective use of simple examples to introduce new concepts. H. E. VIGOUR

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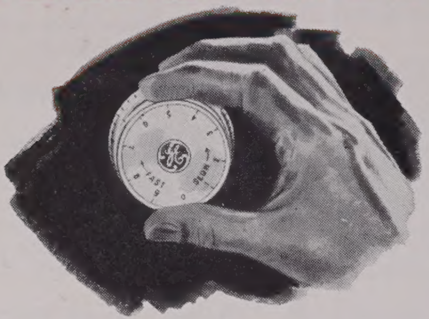

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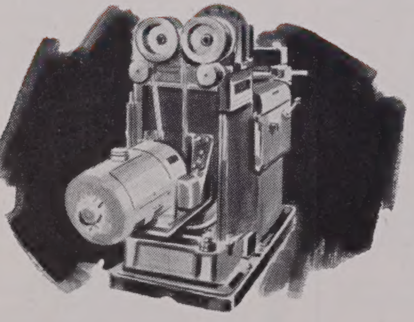

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